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# Energy Assessment at Army Installations in Germany

## Campbell Barracks – Heidelberg, Coleman Barracks – Manheim, Katterbach Barracks – Ansbach, Storch Barracks – Illesheim, and U.S. Depot – Germersheim

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Final Report



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**Abstract:** An Energy Optimization Assessment was conducted at several Army installations in Germany as a part of the International Energy Agency (IEA) Energy Conservation in Buildings and Community Systems (ECBCS) initiative to identify energy inefficiencies and wastes and propose energy-related projects with applicable funding and execution methods that could enable installations to better meet the energy reduction requirements mandated by Executive Order 13123 and Energy Policy Act (EPAct) 2005. Previous studies were conducted at: Fort Stewart GA; Fort Bliss TX; West Point Military Academy, NY; U.S. Army Garrison (USAG) Vicenza, Italy; and several sites in Germany. Results of those studies are documented separately. The study was conducted by the Energy Team, composed of the Construction Engineering Research Laboratory (ERDC-CERL) researchers and their subject matter experts. The scope of the Annex 46 Energy Optimization Assessment included a Level I study of the central energy plants and associated steam distribution systems providing heat to representative administrative buildings, laundry, dining facilities and other buildings and an analysis of their building envelopes, ventilation air systems, and lighting. The study identified 87 different energy conservation measures (ECMs) that would reduce annual electrical use by up to 9.3 million kWh and thermal energy use by 27,545 MMBtu/yr.

# Executive Summary

## Summary

This Energy Optimization Assessment at several Army installations (Campbell Barracks—Heidelberg, Coleman Barracks—Manheim, Katterbach Barracks—Ansbach, Storch Barracks—Illesheim, and U.S. Army Depot—Germersheim) was done as a part of the Annex 46 showcase studies to identify energy inefficiencies and wastes and to propose energy-related projects with applicable funding and execution methods that could enable installations to better meet the energy reduction requirements mandated by Executive Order 13423 and EPACT 2005. The study was limited to a Level I assessment; its scope included an analysis of building envelopes, ventilation air systems, controls, central heating plants, interior and exterior lighting; and an evaluation of opportunities to use renewable energy resources.

The study identified 87 different potential energy conservation measures (ECMs) (Table ES1). If all were implemented, these ECMs would result in savings of ~€1.7 million/yr (9,331 MWh/yr in electrical energy savings and 27,545 MMBtu/yr in thermal savings). Implementation of these projects would require an investment of €14.8 million. Renewables, Central Energy Plants (CEP), Radiant Heating, Lighting, and HVAC had the largest cost savings of the facilities visited. In addition to the ECMs discussed in this report, this work also investigated the potential for solar heating of domestic hot water. However, due to the long paybacks (in excess of 20 years), these ECMs are included as Appendix A. Several opportunities such as optimization of CEPs are applicable to most any installation in Germany, so the potential summarized here is a small fraction of the total potential.

The best opportunities, as judged simple payback (investment divided by yearly savings), were found in ECMs that apply to all facilities (referred to as “Multiple” [MUL] in Table ES1), Central Energy Plants, and HVAC. All are believed to have aggregate paybacks of less than 4 years. ECMs for dining facilities also had very good paybacks with an aggregate simple payback of 5.5 years. Renewables, which have an aggregate payback of 11 years, should also be considered since funding opportunities such as the Energy Conservation Investment Program (ECIP), can give them special consideration regardless of their relatively long payback periods.

Table ES1. All identified potential ECMs.

| ECM | ECM Description | Electricity Savings | | | Thermal | | Maintenance €/Yr | Total Savings: Electrical Use, Elec Demand, Thermal, and Maint €/Yr | Investment € | Simple Payback Years |
|---|---|---|---|---|---|---|---|---|---|---|
| | | MMBtu/Yr | KWh/yr | €/Yr | MMBtu/Yr | €/Yr | | | | |
| BE #1CO | Install Panels in Areas Having Single Pane Windows, Bldg 25 | 0 | 0 | € 0 | 124 | € 1,336 | 0 | € 1,336 | € 19,800 | 14.8 |
| BE #2CO | Reduce Door Size, Bldg 49 | 0 | 0 | € 0 | 290 | € 3,132 | 0 | € 3,132 | € 44,500 | 14.2 |
| BE #3US | Reduce Door Size, Bldgs 7938 and 7941 | 0 | 0 | € 0 | 232 | € 2,499 | 0 | € 2,499 | € 30,300 | 12.1 |
| DIN #1CA | Utilize Kitchen Hood Control, Bldg 112 | 91 | 26,630 | € 2,378 | 458 | € 4,938 | 0 | € 7,316 | € 42,200 | 5.8 |
| DIN #2CO | Modify Kitchen Hoods with End Skirts and Temperature Controlled Exhaust, Bldg 45 | 87 | 25,400 | € 3,629 | 240 | € 2,588 | 0 | € 6,217 | € 40,600 | 6.5 |
| DIN #3CO | Use Low Flow Pre-Rinse Kitchen Nozzles | 0 | 0 | € 0 | 146 | € 1,574 | 0 | € 1,574 | € 80 | 0.1 |
| CEP #1CA | Analysis of the Secondary Heating System Pumps, Adjustment of the Size and Operation Mode | 0 | 2,700 | € 241 | 0 | 0 | 0 | € 241 | € 2,500 | 10.4 |
| CEP #2CA | Additional Bio-Diesel Fired Cogeneration Motor | 0 | 2,250,000 | 0 | 10,239 | 0 | € 28,362 | € 171,000 | € 449,000 | 15* |
| CEP #3CA | Optimization of the Central Cooling System | 0 | 0 | 0 | 314 | € 26,900 | 0 | € 26,900 | € 343,000 | 12.8 |
| CEP #4CO | Substation Optimization - Coleman Barracks | 0 | 136,080 | € 27,216 | 0 | 0 | 0 | € 27,216 | € 45,000 | 1.7 |
| CEP #5US | Connection of the “Big O” Bldgs to the Central Heating System | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| HVAC #1CA | Repair Leaking Hot Water Valve, Bldg 18 | 536 | 157,000 | € 14,020 | 1,611 | € 17,370 | 0 | € 31,390 | € 2,000 | 0.1 |
| HVAC #2CA | Adjust HVAC Unit Outdoor Air Using $CO_2$ sensors, Bldg 22 | 16 | 4,800 | € 429 | 505 | € 5,446 | 0 | € 5,875 | € 4,000 | 0.7 |
| HVAC #3CA | Modify Bldg Controls to allow HVAC Unit not use 100% Outside Air, Bldg 18 | 82 | 23,900 | € 2,134 | 2,536 | € 27,342 | 0 | € 29,477 | € 1,000 | 0.0 |
| HVAC #4CA | Install Absorption Chiller driven by Solar Collectors to Replace Electric Chiller - Bldg 3983 | 0 | 89,000 | € 7,948 | 0 | € 0 | 0 | € 7,948 | € 240,000 | 30.2 |
| HVAC #5CO | Reduce Pressure and Recover Waste Heat from Air Compressor, Motor Pool Bldg 57 | 10 | 2,860 | € 255 | 20 | € 221 | 0 | € 476 | € 1,000 | 2.1 |
| HVAC #6CO | Optimize the Use of Compressed Air and the Sizing of the Air Compressors – Hanger Bldg 4 | 444 | 130,000 | € 11,609 | 0 | € 0 | 0 | € 11,609 | € 25,000 | 2.2 |
| HVAC #7CO | Replace Pneumatic Controls with DDC Bldg 4 | 0 | 0 | € 0 | 2,048 | € 22,080 | 0 | € 22,080 | € 150,000 | 6.8 |
| HVAC #8US | Check Temperature Control and Check OA Damper Functions for Unit Heaters Bldg 7902 | 0 | 0 | € 0 | 341 | € 3,680 | 0 | € 3,680 | € 5,000 | 1.4 |
| HVAC #9US | Optimize the Use of Compressed Air and the Sizing of the Air Compressors – Motor Pool Bldg 7902 Germersheim | 154 | 45,000 | € 4,019 | 0 | € 0 | 0 | € 4,019 | € 15,000 | 3.7 |
| LI #1CA | Use Occupancy Sensors to Turn off Lights | 4 | 1,272 | € 114 | 0 | € 0 | 0 | € 114 | € 1,100 | 9.7 |
| LI #2CA | Change Bulbs in Exit Lights | 60 | 17,520 | € 1,565 | 0 | € 0 | € 2,400 | € 3,965 | € 18,000 | 4.5 |
| LI #3CO | Use Occupancy Sensors to Turn off Lights | 77 | 22,633 | € 2,021 | 0 | € 0 | 0 | € 2,021 | € 11,500 | 5.7 |

| ECM | ECM Description | Electricity Savings MMBtu/Yr | Electricity Savings KWh/yr | Electricity Savings €/Yr | Thermal MMBtu/Yr | Thermal €/Yr | Maintenance €/Yr | Total Savings: Electrical Use, Elec Demand, Thermal, and Maint €/Yr | Investment € | Simple Payback Years |
|---|---|---|---|---|---|---|---|---|---|---|
| LI #4CO | Change Bulbs in Exit Lights | 119 | 34,950 | € 3,121 | 0 | € 0 | € 4,800 | € 7,921 | € 36,000 | 4.5 |
| LI #5CO | Reduce Lighting Using Day Lighting Controls, Band Lobby Area, Bldg 25 | 1 | 250 | € 22 | 0 | € 0 | 0 | € 22 | € 400 | 17.9 |
| LI #6CO | Reduce Lighting Using Day Lighting Controls, Storage area Bldgs 49 | 15 | 4,310 | € 385 | 0 | € 0 | 0 | € 385 | € 64,000 | 166.3 |
| LI #7CO | Shut Off Outdoor Lighting in Daytime, Bldg 57 | 4 | 1,235 | € 110 | 0 | € 0 | 0 | € 110 | € 300 | 2.7 |
| LI #8CO | Add Skylights, Bldg 49 | 49 | 14,400 | € 1,286 | 0 | € 0 | 0 | € 1,286 | € 51,000 | 39.7 |
| LI #9CO | Change Bulbs in Exit Lights | 119 | 34,950 | € 3,121 | 0 | € 0 | € 4,800 | € 7,921 | € 36,000 | 4.5 |
| LI #10CO | Reduce Lighting Using Day Lighting Controls, Band Lobby Area, Bldg 25 | 1 | 250 | € 22 | 0 | € 0 | 0 | € 22 | € 400 | 17.9 |
| LI #11CO | Reduce Lighting Using Day Lighting Controls, Storage area Bldgs 49 | 15 | 4,310 | € 385 | 0 | € 0 | 0 | € 385 | € 64,000 | 166.3 |
| LI #12CO | Shut Off Outdoor Lighting in Daytime, Bldg 57 | 4 | 1,235 | € 110 | 0 | € 0 | 0 | € 110 | € 1,000 | 9.1 |
| LI #13CO | Add Skylights, Bldg 49 | 49 | 14,400 | € 1,286 | 0 | € 0 | 0 | € 1,286 | € 51,000 | 39.7 |
| LI #14US | Use Occupancy Sensors To Turn off Lights, Bldg 7951 and 7971 | 121 | 35,583 | € 3,178 | 0 | € 0 | 0 | € 3,178 | € 27,000 | 8.5 |
| LI #15US | Dim Lighting Using Day Lighting Controls, Bldg 7988 | 154 | 45,108 | € 4,028 | 0 | € 0 | 0 | € 4,028 | € 14,400 | 3.6 |
| LI #16US | Install Skylight, Bldgs 7951 and 7988 | 454 | 132,987 | € 11,876 | 0 | € 0 | 0 | € 11,876 | € 141,588 | 11.9 |
| LI #17US | New Lighting System, Bldg 7902 | 382 | 112,000 | € 10,002 | 0 | € 0 | € 1,200 | € 11,202 | € 62,400 | 5.6 |
| LI #18US | New Lighting System, Bldg 7987, 7988, and 7989 | 1,730 | 507,000 | € 45,275 | 0 | € 0 | € 1,700 | € 46,975 | € 448,000 | 9.5 |
| LI #19US | New Light System, Bldg 7971 | 149 | 43,750 | € 3,500 | 0 | € 0 | 0 | € 3,500 | € 17,100 | 4.9 |
| LI #20US | New Light System, Bldg 7973 | 64 | 18,750 | € 1,500 | 0 | € 0 | 0 | € 1,500 | € 13,140 | 8.8 |
| LI #21US | New Light System, Bldg 7974 | 115 | 33,750 | € 2,700 | 0 | € 0 | 0 | € 2,700 | € 13,140 | 4.9 |
| LI #22US | New Light System, Bldg 7975 | 115 | 33,750 | € 2,700 | 0 | € 0 | 0 | € 2,700 | € 13,140 | 4.9 |
| LI #23US | New Light System, Bldg 7976 | 149 | 43,750 | € 3,500 | 0 | € 0 | 0 | € 3,500 | € 17,100 | 4.9 |
| LI #24US | New Light System, Bldg 7977-2 | 512 | 150,000 | € 12,000 | 0 | € 0 | 0 | € 12,000 | € 18,000 | 1.5 |
| LI #25US | New Light System, Bldg 7977-3 | 512 | 137,500 | € 11,000 | 0 | € 0 | 0 | € 11,000 | € 16,500 | 1.5 |
| MUL #1 | Add Buildings to the UEMCS Building Control System | 0 | 0 | € 0 | 0 | € 0 | 0 | € 0 | 0 | 0 |
| MUL #2 | Re-commission Building Controls and HVAC systems | 0 | 0 | € 0 | 0 | € 0 | 0 | € 0 | 0 | 0 |

| ECM | ECM Description | Electricity Savings | | | Thermal | | Maintenance €/Yr | Total Savings: Electrical Use, Elec Demand, Thermal, and Maint €/Yr | Investment € | Simple Payback Years |
|---|---|---|---|---|---|---|---|---|---|---|
| | | MMBtu/Yr | KWh/yr | €/Yr | MMBtu/Yr | €/Yr | | | | |
| MUL #3 | LED Lighting Systems | 0 | 0 | € 0 | 0 | € 0 | 0 | € 0 | 0 | 0 |
| MUL #4 | Optimize Compressed Air Use and Compressor Size Bldg 7902 at Germersheim and Bldg 4 at Coleman Barracks | 0 | 175,000 | € 15,628 | 0 | 0 | 0 | € 15,628 | € 40,000 | 2.6 |
| MUL #5 | Replacement of Circulation Pumps | 0 | 0 | € 0 | 0 | € 0 | 0 | € 0 | 0 | 0 |
| MUL #6 | Switch off boilers, HW pumps, and Chillers Based on Outside Air Temperature Bldg 18 Campbell Barracks and Bldgs 49, 106 at Coleman Barracks | 205 | 60,000 | € 5,358 | 0 | € 0 | 0 | € 5,358 | 0 | 0.0 |
| RAD #1KS | Radiant Heating Katterbach Barracks Bldg 5801 | 0 | 0 | € 0 | 519 | € 12,768 | 0 | € 12,768 | € 103,000 | 8.1 |
| RAD #2KS | Radiant Heating Katterbach Barracks Bldg 5802 | 0 | 0 | € 0 | 440 | € 10,836 | 0 | € 10,836 | € 103,000 | 9.5 |
| RAD #3KS | Radiant Heating Katterbach Barracks Bldg 5806 | 0 | 0 | € 0 | 478 | € 11,760 | 0 | € 11,760 | € 190,000 | 16.2 |
| RAD #4KS | Radiant Heating Katterbach Barracks Bldg 5807 | 0 | 0 | € 0 | 1,270 | € 31,248 | 0 | € 31,248 | € 129,000 | 4.1 |
| RAD #5KS | Radiant Heating Storch Barracks Bldg 6500 | 0 | 0 | € 0 | 1,461 | € 35,952 | 0 | € 35,952 | € 268,000 | 7.5 |
| RAD #6KS | Radiant Heating Storch Barracks Bldg 6501 | 0 | 0 | € 0 | 1,239 | € 30,492 | 0 | € 30,492 | € 268,000 | 8.8 |
| RAD #7KS | Radiant Heating Storch Barracks Bldg 6502 | 0 | 0 | € 0 | 1,464 | € 36,036 | 0 | € 36,036 | € 268,000 | 7.4 |
| RAD #8KS | Radiant Heating Storch Barracks Bldg 6633 | 0 | 0 | € 0 | 457 | € 11,256 | 0 | € 11,256 | € 102,000 | 9.1 |
| REN #1CO | PV System Bldg 25 Coleman Barracks - Manheim | 268 | 78,595 | € 34,813 | | | | € 34,813 | € 368,881 | 10.6 |
| REN #2CO | PV System Bldg 11 Coleman Barracks - Manheim | 153 | 44,744 | € 20,107 | 0 | 0 | 0 | € 20,107 | € 201,297 | 10.0 |
| REN #3CO | PV System Bldg 13 Coleman Barracks - Manheim | 153 | 44,744 | € 20,107 | 0 | 0 | 0 | € 20,107 | € 201,297 | 10.0 |
| REN #4CO | PV System Bldg 15 Coleman Barracks - Manheim | 153 | 44,744 | € 20,107 | 0 | 0 | 0 | € 20,107 | € 201,297 | 10.0 |
| REN #5CO | PV System Bldg 17 Coleman Barracks - Manheim | 153 | 44,744 | € 20,107 | 0 | 0 | 0 | € 20,107 | € 201,297 | 10.0 |
| REN #6CO | PV System Bldg 29 Coleman Barracks - Manheim | 153 | 44,744 | € 20,107 | 0 | 0 | 0 | € 20,107 | € 201,297 | 10.0 |
| REN #7CO | PV System Bldg 31 Coleman Barracks - Manheim | 153 | 44,744 | € 20,107 | 0 | 0 | 0 | € 20,107 | € 201,297 | 10.0 |
| REN #8CO | PV System Bldg 33 Coleman Barracks - Manheim | 153 | 44,744 | € 20,107 | 0 | 0 | 0 | € 20,107 | € 201,297 | 10.0 |
| REN #9CO | PV System Bldg 35 Coleman Barracks - Manheim | 153 | 44,744 | € 20,107 | 0 | 0 | 0 | € 20,107 | € 201,297 | 10.0 |
| REN #10KS | PV System Bldg 9021 - Katterbach Barracks, Ansbach | 136 | 39,853 | € 17,720 | 0 | € 0 | 0 | € 17,720 | € 197,615 | 11.2 |
| REN #11KS | PV System Bldg 5810 - Katterbach Barracks, Ansbach | 183 | 53,650 | € 23,955 | 0 | € 0 | 0 | € 23,955 | € 248,848 | 10.4 |

| ECM | ECM Description | Electricity Savings | | | Thermal | | Maintenance €/Yr | Total Savings: Electrical Use, Elec Demand, Thermal, and Maint €/Yr | Investment € | Simple Payback Years |
|---|---|---|---|---|---|---|---|---|---|---|
| | | MMBtu/Yr | KWh/yr | €/Yr | MMBtu/Yr | €/Yr | | | | |
| REN #12KS | PV System Bldg 5819 - Katterbach Barracks, Ansbach | 178 | 52,123 | € 23,292 | 0 | € 0 | 0 | € 23,292 | € 241,529 | 10.4 |
| REN #13KS | PV System Open Space - Katterbach Barracks, Ansbach | 877 | 256,943 | € 111,469 | 0 | € 0 | 0 | € 111,469 | € 1,268,027 | 11.4 |
| REN #14KS | PV System Bldg 6629 – Storch Barracks, Illesheim | 286 | 83,925 | € 37,093 | 0 | € 0 | 0 | € 37,093 | € 395,229 | 10.7 |
| REN #15KS | PV System Bldg 6630 – Storch Barracks, Illesheim | 286 | 83,925 | € 37,093 | 0 | € 0 | 0 | € 37,093 | € 395,229 | 10.7 |
| REN #16KS | PV System Bldg 6608 – Storch Barracks, Illesheim | 203 | 59,533 | € 26,497 | 0 | € 0 | 0 | € 26,497 | € 285,443 | 10.8 |
| REN #17KS | PV System Bldg 6610 – Storch Barracks, Illesheim | 202 | 59,222 | € 26,350 | 0 | € 0 | 0 | € 26,350 | € 285,443 | 10.8 |
| REN #18KS | PV System Bldg 6612 – Storch Barracks, Illesheim | 201 | 59,023 | € 26,261 | 0 | € 0 | 0 | € 26,261 | € 285,443 | 10.9 |
| REN #19KS | PV System Bldg 6517 – Storch Barracks, Illesheim | 216 | 63,262 | € 28,148 | 0 | € 0 | 0 | € 28,148 | € 285,443 | 10.1 |
| REN #20KS | PV System Bldg 6633 – Storch Barracks, Illesheim | 68 | 20,070 | € 9,163 | 0 | € 0 | 0 | € 9,163 | € 96,804 | 10.6 |
| REN #21KS | PV System Open Space – Storch Barracks, Illesheim | 877 | 256,943 | € 111,469 | 0 | € 0 | 0 | € 111,469 | € 1,268,027 | 11.4 |
| REN #22US | Solar Wall, Bldgs 7950, 7951, 7954, 7955, 7971, and 7972 | 0 | 0 | € 0 | 1,113 | € 11,997 | 0 | € 11,997 | € 444,500 | 37.1 |
| REN #23US | Install a Wind Mill at Germersheim | 10,236 | 3,000,000 | € 267,900 | 0 | € 0 | -€ 45,000 | € 222,900 | € 2,000,000 | 9.0 |
| REN #24US | Photovoltaics Bldg 7889 - U.S. Depot Germersheim | 159 | 46,503 | € 20,843 | 0 | 0 | 0 | € 20,843 | € 218,208 | 10.5 |
| REN #25US | Photovoltaics Bldg 7823 - U.S. Depot Germersheim | 187 | 54,872 | € 24,481 | 0 | 0 | 0 | € 24,481 | € 265,167 | 10.8 |
| REN #26US | Photovoltaics Bldg 7834 - U.S. Depot Germersheim | 46 | 13,346 | € 6,135 | 0 | 0 | 0 | € 6,135 | € 64,534 | 10.5 |
| REN #27US | Photovoltaics Bldg 7846 - U.S. Depot Germersheim | 187 | 54,931 | € 24,508 | 0 | 0 | 0 | € 24,508 | € 256,167 | 10.5 |
| REN #28US | Photovoltaics Bldg 7826 - U.S. Depot Germersheim | 212 | 62,229 | € 27,688 | 0 | 0 | 0 | € 27,688 | € 285,443 | 10.3 |
| *Totals* | | *22,828* | *9,330,913* | *1,265,402* | *27,545* | *311,451* | *-1,738* | *1,717,752* | *14,833,544* | *8.6* |

At **Campbell Barracks**, 10 ECMs were identified with simple paybacks ranging from immediate (modification of HVAC controls) to 30 years for an absorption chiller run from solar heat (Table ES2). Obviously implementation of the ECMs identified should be done only after considering the economic situation.

At **Coleman Barracks**, 28 ECMs were identified (Table ES3). They would save 164 MWh/yr in electrical use and 821 MMBtu/yr in heating costs for a total of €40K savings per year. The investment cost of €151K results in a quick simple payback of 3.8 years.

At **Katterbach and Storch Barracks**, 20 ECMs were identified (Table ES4). They would save 1,088 MWh/yr in electrical use and 7,328 MMBtu/yr in heating costs for a total of €659K savings per year. The investment cost of €6.7 million results in a relatively long payback of 10 years. While this is generally considered a relatively long payback period, the majority of them are renewable. Considering the emphasis on renewables and the likely increase in energy costs, these are attractive opportunities. Eight buildings were identified as having potential for radiant heating. The analysis includes a price quote from a local vendor and 30 percent design drawings.

At **U.S. Army Depot – Germersheim**, 23 ECMs were identified (Table ES5). They would save 4,571 MWh/yr in electrical use and 1,686 MMBtu/yr in heating costs for a total of €463K savings per year. The investment cost of €4.4 million results in a relatively long payback of 9.5 years. While this is generally considered a relatively long payback period, many of them are renewable. Considering the emphasis on renewables and the likely increase in energy costs, these are attractive opportunities. Others such as new lighting systems in Bldg 7977 have very good payback period of 1.5 years.

For **Multiple Facilities**, six ECMs were identified that apply in general to all facilities. All were expected to have excellent paybacks.

The Level I analyses of multiple complex systems conducted during the Energy Optimization Assessment are not intended to be (nor should they be) precise. The quantity and quality of the systems improvements identified suggests that significant potential exists.

Table ES2. Summary of Campbell Barracks ECMs.

| ECM # | ECM Description | Electrical Savings KWh/yr | Electrical Savings €/Yr | Thermal MMBtu/Yr | Thermal €/Yr | Maintenance €/Yr | Total Savings: Electrical Use, Elec Demand, Thermal, and Maint €/Yr | Investment € | Simple Payback (yrs) |
|---|---|---|---|---|---|---|---|---|---|
| CEP #1CA | Analysis of the Secondary Heating System Pumps, Adjustment of the Size and Operation Mode | 2,700 | €241 | 0 | €0 | €0 | €241 | €2,500 | 10.4 |
| CEP #2CA | Additional Bio-Diesel Fired Cogeneration Motor | 2,250,000 | €0 | 10239 | €0 | €28,362 | €171,000 | €449,000 | 15* |
| CEP #3CA | Optimization of the Central Cooling System | 0 | €0 | 314 | €26,900 | €0 | €26,900 | €343,000 | 12.8 |
| DIN #1CA | Utilize Kitchen Hood Control, Bldg 112 | 26,630 | €2,378 | 458 | €4,938 | €0 | €7,316 | €42,200 | 5.8 |
| HVAC #1CA | Repair Leaking Hot Water Valve, Bldg 18 | 157,000 | €14,020 | 1611 | €17,370 | €0 | €31,390 | €2,000 | 0.1 |
| HVAC #2CA | Adjust HVAC Unit Outdoor Air Using $CO_2$ sensors, Bldg 22 | 4,800 | €429 | 505 | €5,446 | €0 | €5,875 | €4,000 | 0.7 |
| HVAC #3CA | Modify Building Controls To Allow HVAC Unit Not Use 100% Outside Air, Bldg 18 | 23,900 | €2,134 | 2536 | €27,342 | €0 | €29,477 | €1,000 | 0.0 |
| HVAC #4CA | Install Absorption Chiller driven by Solar Collectors To Replace Electric Chiller. Bldg 3983 | 89,000 | €7,948 | 0 | €0 | €0 | €7,948 | €240,000 | 30.2 |
| LI #1CA | Use Occupancy Sensors To Turn off Lights | 1,272 | €114 | 0 | €0 | €0 | €114 | €1,100 | 9.7 |
| LI #2CA | Change Bulbs in Exit Lights | 17,520 | €1,565 | 0 | €0 | €2,400 | €3,965 | €18,000 | 4.5 |
| *Totals* | | *2,572,822* | *28,828* | *15,663* | *81,997* | *30,762* | *284,225* | *1,102,800* | *4* |

** Payback of 15 years for CEP #2CA is the result of a life cycle analysis that includes costs not easily explained in this table.*

Table ES3. Summary of Coleman Barracks ECMs.

| ECM # | ECM Description | Electrical Savings KWh/yr | Electrical Savings €/Yr | Thermal MMBtu/Yr | Thermal €/Yr | Maintenance €/Yr | Total Savings: Electrical Use, Elec Demand, Thermal, and Maint €/Yr | Investment € | Simple Payback Years |
|---|---|---|---|---|---|---|---|---|---|
| BE #1CO | Install Panels in Areas Having Single Pane Windows, Bldg 25 | 0 | € 0 | 124 | € 1,336 | € 0 | € 1,336 | € 19,800 | 14.8 |
| BE #2CO | Reduce Door Size, Bldg 49 | 0 | € 0 | 290 | € 3,132 | € 0 | € 3,132 | € 44,500 | 14.2 |
| DIN #2CO | Modify Kitchen Hoods with End Skirts and Temperature Controlled Exhaust, Bldg 45 | 25,400 | € 3,629 | 240 | € 2,588 | € 0 | € 6,217 | € 40,600 | 6.5 |
| DIN #3CO | Use Low Flow Pre-rinse Kitchen Nozzles | 0 | € 0 | 146 | € 1,574 | € 0 | € 1,574 | € 80 | 0.1 |
| CEP #4CO | Substation Optimization, Coleman Barracks | 136,080 | € 27,216 | 0 | € 0 | € 0 | € 27,216 | € 45,000 | 1.7 |
| HVAC #5CO | Reduce Pressure and Recover Waste Heat from Air Compressor, Motor Pool Bldg 57 | 2,860 | € 255 | 20 | € 221 | € 0 | € 476 | € 1,000 | 2.1 |
| HVAC #6CO | Optimize the Use of Compressed Air and the Sizing of the Air Compressors, Hanger Bldg 4 | 130,000 | € 11,609 | 0 | € 0 | € 0 | € 11,609 | € 25,000 | 2.2 |
| HVAC #7CO | Replace Pneumatic Controls with DDC Bldg 4 | 0 | € 0 | 2048 | € 22,080 | € 0 | € 22,080 | € 150,000 | 6.8 |
| LI #3CO | Use Occupancy Sensors To Turn off Lights | 22,633 | € 2,021 | 0 | € 0 | € 0 | € 2,021 | € 11,500 | 5.7 |
| LI #4CO | Change Bulbs in Exit Lights | 34,950 | € 3,121 | 0 | € 0 | € 4,800 | € 7,921 | € 36,000 | 4.5 |
| LI #5CO | Reduce Lighting Using Day Lighting Controls, Band Lobby Area, Bldg 25 | 250 | € 22 | 0 | € 0 | € 0 | € 22 | € 400 | 17.9 |
| LI #6CO | Reduce Lighting Using Day Lighting Controls, Storage area Bldgs 49 | 4,310 | € 385 | 0 | € 0 | € 0 | € 385 | € 64,000 | 166.3 |
| LI #7CO | Shut off Outdoor Lighting in Daytime, Bldg 57 | 1,235 | € 110 | 0 | € 0 | € 0 | € 110 | € 300 | 2.7 |
| LI #8CO | Add Skylights, Bldg 49 | 14,400 | € 1,286 | 0 | € 0 | € 0 | € 1,286 | € 51,000 | 39.7 |
| LI #9CO | Change Bulbs in Exit Lights | 34,950 | € 3,121 | 0 | € 0 | € 4,800 | € 7,921 | € 36,000 | 4.5 |
| LI #10CO | Reduce Lighting Using Day Lighting Controls, Band Lobby Area, Bldg 25 | 250 | € 22 | 0 | € 0 | € 0 | € 22 | € 400 | 17.9 |
| LI #11CO | Reduce Lighting Using Day Lighting Controls, Storage area Bldgs 49 | 4,310 | € 385 | 0 | € 0 | € 0 | € 385 | € 64,000 | 166.3 |
| LI #12CO | Shut off Outdoor Lighting in Daytime, Bldg 57 | 1,235 | € 110 | 0 | € 0 | € 0 | € 110 | € 1,000 | 9.1 |
| LI #13CO | Add Skylights, Bldg 49 | 14,400 | € 1,286 | 0 | € 0 | € 0 | € 1,286 | € 51,000 | 39.7 |
| REN #1CO | PV System Bldg 25 Coleman Barracks - Manheim | 78,595 | € 34,813 | 0 | € 0 | € 0 | € 34,813 | € 368,881 | 10.6 |
| REN #2CO | PV System Bldg 11 Coleman Barracks - Manheim | 44,744 | € 20,107 | 0 | € 0 | € 0 | € 20,107 | € 201,297 | 10.0 |
| REN #3CO | PV System Bldg 13 Coleman Barracks - Manheim | 44,744 | € 20,107 | 0 | € 0 | € 0 | € 20,107 | € 201,297 | 10.0 |
| REN #4CO | PV System Bldg 15 Coleman Barracks - Manheim | 44,744 | € 20,107 | 0 | € 0 | € 0 | € 20,107 | € 201,297 | 10.0 |
| REN #5CO | PV System Bldg 17 Coleman Barracks - Manheim | 44,744 | € 20,107 | 0 | € 0 | € 0 | € 20,107 | € 201,297 | 10.0 |
| REN #6CO | PV System Bldg 29 Coleman Barracks - Manheim | 44,744 | € 20,107 | 0 | € 0 | € 0 | € 20,107 | € 201,297 | 10.0 |
| REN #7CO | PV System Bldg 31 Coleman Barracks - Manheim | 44,744 | € 20,107 | 0 | € 0 | € 0 | € 20,107 | € 201,297 | 10.0 |
| REN #8CO | PV System Bldg 33 Coleman Barracks - Manheim | 44,744 | € 20,107 | 0 | € 0 | € 0 | € 20,107 | € 201,297 | 10.0 |
| REN #9CO | PV System Bldg 35 Coleman Barracks - Manheim | 44,744 | € 20,107 | 0 | € 0 | € 0 | € 20,107 | € 201,297 | 10.0 |
| *Totals* | | *164,340* | *€ 31,101* | *821* | *€ 8,850* | *€ 0* | *€ 39,951* | *€ 150,980* | *3.8* |

Table ES4. Summary of Katterbach and Storch Barracks ECMs.

| ECM # | ECM Description | Electrical Savings | | Thermal | | Maintenance €/Yr | Total Savings: Electrical Use, Elec Demand, Thermal, and Maint €/yr | Investment € | Simple Payback yrs |
|---|---|---|---|---|---|---|---|---|---|
| | | KWh/yr | €/Yr | MMBtu/Yr | €/Yr | | | | |
| RAD #1KS | Radiant Heating, Katterbach Barracks Bldg 5801 | 0 | €0 | 519 | €12,768 | €0 | €12,768 | €103,000 | 8.1 |
| RAD #2KS | Radiant Heating, Katterbach Barracks Bldg 5802 | 0 | €0 | 440 | €10,836 | €0 | €10,836 | €103,000 | 9.5 |
| RAD #3KS | Radiant Heating, Katterbach Barracks Bldg 5806 | 0 | €0 | 478 | €11,760 | €0 | €11,760 | €190,000 | 16.2 |
| RAD #4KS | Radiant Heating, Katterbach Barracks Bldg 5807 | 0 | €0 | 1270 | €31,248 | €0 | €31,248 | €129,000 | 4.1 |
| RAD #5KS | Radiant Heating, Storch Barracks Bldg 6500 | 0 | €0 | 1461 | €35,952 | €0 | €35,952 | €268,000 | 7.5 |
| RAD #6KS | Radiant Heating, Storch Barracks Bldg 6501 | 0 | €0 | 1239 | €30,492 | €0 | €30,492 | €268,000 | 8.8 |
| RAD #7KS | Radiant Heating, Storch Barracks Bldg 6502 | 0 | €0 | 1464 | €36,036 | €0 | €36,036 | €268,000 | 7.4 |
| RAD #8KS | Radiant Heating, Storch Barracks Bldg 6633 | 0 | €0 | 457 | €11,256 | €0 | €11,256 | €102,000 | 9.1 |
| REN #10KS | PV System, Bldg 9021 - Katterbach Barracks, Ansbach | 39,853 | €17,720 | 0 | €0 | €0 | €17,720 | €197,615 | 11.2 |
| REN #11KS | PV System, Bldg 5810 - Katterbach Barracks, Ansbach | 53,650 | €23,955 | 0 | €0 | €0 | €23,955 | €248,848 | 10.4 |
| REN #12KS | PV System, Bldg 5819 - Katterbach Barracks, Ansbach | 52,123 | €23,292 | 0 | €0 | €0 | €23,292 | €241,529 | 10.4 |
| REN #13KS | PV System Open Space, Katterbach Barracks, Ansbach | 256,943 | €111,469 | 0 | €0 | €0 | €111,469 | €1,268,027 | 11.4 |
| REN #14KS | PV System Bldg 6629, Storch Barracks, Illesheim | 83,925 | €37,093 | 0 | €0 | €0 | €37,093 | €395,229 | 10.7 |
| REN #15KS | PV System Bldg 6630, Storch Barracks, Illesheim | 83,925 | €37,093 | 0 | €0 | €0 | €37,093 | €395,229 | 10.7 |
| REN #16KS | PV System Bldg 6608, Storch Barracks, Illesheim | 59,533 | €26,497 | 0 | €0 | €0 | €26,497 | €285,443 | 10.8 |
| REN #17KS | PV System Bldg 6610, Storch Barracks, Illesheim | 59,222 | €26,350 | 0 | €0 | €0 | €26,350 | €285,443 | 10.8 |
| REN #18KS | PV System Bldg 6612, Storch Barracks, Illesheim | 59,023 | €26,261 | 0 | €0 | €0 | €26,261 | €285,443 | 10.9 |
| REN #19KS | PV System Bldg 6517, Storch Barracks, Illesheim | 63,262 | €28,148 | 0 | €0 | €0 | €28,148 | €285,443 | 10.1 |
| REN #20KS | PV System Bldg 6633, Storch Barracks, Illesheim | 20,070 | €9,163 | 0 | €0 | €0 | €9,163 | €96,804 | 10.6 |
| REN #21KS | PV System Open Space, Storch Barracks, Illesheim | 256,943 | €111,469 | 0 | €0 | €0 | €111,469 | €1,268,027 | 11.4 |
| *Totals* | | *1,088,472* | *€478,509* | *7328* | *€180,348* | *€0* | *€658,857* | *€6,684,080* | *10.1* |

Table ES5. Summary of U.S. Army Depot – Germersheim ECMs.

| ECM # | ECM Description | Electrical Savings | | Thermal | | Maintenance €/yr | Total Savings: Electrical Use, Elec Demand, Thermal, and Maint (€/yr) | Investment € | Simple Payback yrs |
|---|---|---|---|---|---|---|---|---|---|
| | | KWh/yr | €/yr | MMBtu/yr | €/yr | | | | |
| BE #3US | Reduce Door Size, Bldgs 7938 and 7941 | 0 | €0 | 232 | €2,499 | €0 | €2,499 | €30,300 | 12.1 |
| CEP #5US | Connection of the "Big O" Buildings to the Central Heating System | 0 | €0 | 0 | €0 | €0 | €0 | €0 | 0.0 |
| HVAC #8US | Check Temperature Control and Check OA Damper Functions for Unit Heaters Bldg 7902 | 0 | €0 | 341 | €3,680 | €0 | €3,680 | €5,000 | 1.4 |
| HVAC #9US | Optimize the Use of Compressed Air and the Sizing of the Air Compressors, Motor Pool Bldg 7902 Germersheim | 45,000 | €4,019 | 0 | €0 | €0 | €4,019 | €15,000 | 3.7 |
| LI #14US | Use Occupancy Sensors to Turn off Lights, Bldgs 7951 and 7971 | 35,583 | €3,178 | 0 | €0 | €0 | €3,178 | €27,000 | 8.5 |
| LI #15US | Dim Lighting Using Day Lighting Controls, Bldg 7988 | 45,108 | €4,028 | 0 | €0 | €0 | €4,028 | €14,400 | 3.6 |
| LI #16US | Install Skylight, Bldgs 7951 and 7988 | 132,987 | €11,876 | 0 | €0 | €0 | €11,876 | €141,588 | 11.9 |
| LI #17US | New Lighting System, Bldg 7902 | 112,000 | €10,002 | 0 | €0 | €1,200 | €11,202 | €62,400 | 5.6 |
| LI #18US | New Lighting System, Bldgs 7987, 7988, and 7989 | 507,000 | €45,275 | 0 | €0 | €1,700 | €46,975 | €448,000 | 9.5 |
| LI #19US | New Light System, Bldg 7971 | 43,750 | €3,500 | 0 | €0 | €0 | €3,500 | €17,100 | 4.9 |
| LI #20US | New Light System, Bldg 7973 | 18,750 | €1,500 | 0 | €0 | €0 | €1,500 | €13,140 | 8.8 |
| LI #21US | New Light System, Bldg 7974 | 33,750 | €2,700 | 0 | €0 | €0 | €2,700 | €13,140 | 4.9 |
| LI #22US | New Light System, Bldg 7975 | 33,750 | €2,700 | 0 | €0 | €0 | €2,700 | €13,140 | 4.9 |
| LI #23US | New Light System, Bldg 7976 | 43,750 | €3,500 | 0 | €0 | €0 | €3,500 | €17,100 | 4.9 |
| LI #24US | New Light System, Bldg 7977-2 | 150,000 | €12,000 | 0 | €0 | €0 | €12,000 | €18,000 | 1.5 |
| LI #25US | New Light System, Bldg 7977-3 | 137,500 | €11,000 | 0 | €0 | €0 | €11,000 | €16,500 | 1.5 |
| REN #22US | Solar Wall, Bldgs 7950, 7951, 7954, 7955, 7971, and 7972 | 0 | €0 | 1113 | €11,997 | €0 | €11,997 | €444,500 | 37.1 |
| REN #23US | Install a Wind Mill at Germersheim | 3,000,000 | €267,900 | 0 | €0 | -€45,000 | €222,900 | €2,000,000 | 9.0 |
| REN #24US | Photovoltaics Bldg 7889, U.S. Depot Germersheim | 46,503 | €20,843 | 0 | €0 | €0 | €20,843 | €218,208 | 10.5 |
| REN #25US | Photovoltaics Bldg 7823, U.S. Depot Germersheim | 54,872 | €24,481 | 0 | €0 | €0 | €24,481 | €265,167 | 10.8 |
| REN #26US | Photovoltaics Bldg 7834, U.S. Depot Germersheim | 13,346 | €6,135 | 0 | €0 | €0 | €6,135 | €64,534 | 10.5 |
| REN #27US | Photovoltaics Bldg 7846, U.S. Depot Germersheim | 54,931 | €24,508 | 0 | €0 | €0 | €24,508 | €256,167 | 10.5 |
| REN #28US | Photovoltaics Bldg 7826, U.S. Depot Germersheim | 62,229 | €27,688 | 0 | €0 | €0 | €27,688 | €285,443 | 10.3 |
| *Totals* | | *4,570,809* | *€486,830* | *1686* | *€18,176* | *-€42,100* | *€462,906* | *€4,385,827* | *9.5* |

## Recommendations

ECMs that apply to all facilities (Table ES6, and rows labeled “Multiple” in Table ES1), Central Energy Plants, Dining Facilities, and HVAC should be pursued. All had aggregate paybacks of less than 6 years. Renewables, which have an aggregate payback of 11 years, should also be pursued since there are funding opportunities such as ECIP, which give them special consideration without regard for their relatively long payback periods.

### Central Energy Plants

The central energy plants were found to be in very good condition. The best project was found to be the optimization of the substation pumping. At Coleman Barracks, this could save €27K per year. An investment of €45K results in a simple payback of 1.7 years. It is recommended that this be pursued either with internal funds or other funds that become available.

### Low to Moderate Cost Projects

The 18 ECMs summarized in Table ES7 were found to have an investment of €20K or less and result in a simple payback of 6 years or less. All could be implemented for a total of €167K, save €127K/yr, and result in a simple payback of just over 1.2 years. Internal funding for these projects should be sought.

### Good Payback and Moderate Investment Projects

Table ES8 lists 10 ECMs that simple paybacks of less than 10 years, but that require moderate investments of between €20K and €200K. These ECMs together would have annual savings of €134K at a cost of €627K for a simple payback of 4.7 years.

### Good Payback and Significant Investment Projects

Nineteen ECMs were found to have significant investment requirements (over €200K) and payback periods of 10 years of less (Table ES9). The majority of them are renewable. Renewable projects with a quick a payback are difficult to find. It is recommended that they be pursued aggressively. The ECIP program is particularly well suited to these larger renewable investment projects.

Table ES6. Summary of ECMs that apply to multiple facilities.

| ECM # | ECM Description | Electrical Savings | | Thermal | | Maintenance €/yr | Total Savings: Electrical Use, Elec Demand, Thermal, and Maint (€/yr) | Investment € | Simple Payback yrs |
|---|---|---|---|---|---|---|---|---|---|
| | | KWh/yr | €/yr | MMBtu/yr | €/yr | | | | |
| MUL #1 | Add Buildings to the UEMCS Building Control System | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - |
| MUL #2 | Re-Commission Building Controls and HVAC systems | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MUL #3 | LED Lighting Systems | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - |
| MUL #4 | Optimize Compressed Air Use and Compressor Size Bldg 7902 at Germersheim, and Bldg 4 at Coleman Barracks | 175,000 | 15,628 | 0 | 0 | 0 | 15,628 | 40,000 | 3 |
| MUL #5 | Replacement of Circulation Pumps | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - |
| MUL #6 | Switch off boilers, HW pumps, and Chillers Based On Outside Air Temperature Bldg 18 Campbell Barracks and Bldgs 49, 106 at Coleman Barracks | 60,000 | 5,358 | 0 | 0 | 0 | 5,358 | 0 | 0 |
| *Totals* | | *235,000* | *€20,986* | *0* | *€0* | *€0* | *€20,986* | *€40,000* | *1.9* |

Table ES7. ECMs with investment < €20K and simple payback < 6 yrs.

| ECM# | ECM Description | Electrical Savings | | Thermal | | Maintenance | Total Savings: Electrical Use, Elec Demand, Thermal, and Maint (€/Yr) | Investment € | Simple Payback yrs |
|---|---|---|---|---|---|---|---|---|---|
| | | KWh/yr | €/Yr | MMBtu/Yr | €/Yr | €/Yr | | | |
| MUL #6 | Switch off boilers, HW pumps, and Chillers Based On Outside Air Temperature Bldg 18 Campbell Barracks and Bldgs 49, 106 at Coleman Barracks | 60,000 | 5,358 | 0 | 0 | 0 | 5,358 | 0 | 0 |
| DIN #3CO | Use Low Flow Pre-rinse Kitchen Nozzles | 0 | 0 | 146 | 1,574 | 0 | 1,574 | 80 | 0 |
| LI #25US | New Light System Bldg 7977-3 | 137,500 | 11,000 | 0 | 0 | 0 | 11,000 | 16,500 | 2 |
| HVAC #1CA | Repair Leaking Hot Water Valve, Bldg 18 | 157,000 | 14,020 | 1,611 | 17,370 | 0 | 31,390 | 2,000 | 0 |
| HVAC #2CA | Adjust HVAC Unit Outdoor Air Using $CO_2$ sensors, Bldg 22 | 4,800 | 429 | 505 | 5,446 | 0 | 5,875 | 4,000 | 1 |
| HVAC #3CA | Modify Building Controls To Allow HVAC Unit To Not Use 100% Outside Air, Bldg 18 | 23,900 | 2,134 | 2,536 | 27,342 | 0 | 29,477 | 1,000 | 0 |
| HVAC #5CO | Reduce Pressure and Recover Waste Heat from Air Compressor, Motor Pool Bldg 57 | 2,860 | 255 | 20 | 221 | 0 | 476 | 1,000 | 2 |
| HVAC #8US | Check Temperature Control and Check OA Damper Functions for Unit Heaters, Bldg 7902 | 0 | 0 | 341 | 3,680 | 0 | 3,680 | 5,000 | 1 |
| HVAC #9US | Optimize Use of Compressed Air and Sizing of the Air Compressors, Motor Pool Bldg 7902 Germersheim | 45,000 | 4,019 | 0 | 0 | 0 | 4,019 | 15,000 | 4 |
| LI #2CA | Change Bulbs in Exit Lights | 17,520 | 1,565 | 0 | 0 | 2,400 | 3,965 | 18,000 | 5 |
| LI #3CO | Use Occupancy Sensors To Turn off Lights | 22,633 | 2,021 | 0 | 0 | 0 | 2,021 | 11,500 | 6 |
| LI #7CO | Shut off Outdoor Lighting in Daytime, Bldg 57 | 1,235 | 110 | 0 | 0 | 0 | 110 | 300 | 3 |
| LI #24US | New Light System Bldg 7977-2 | 150,000 | 12,000 | 0 | 0 | 0 | 12,000 | 18,000 | 2 |
| LI #15US | Dim Lighting Using Day Lighting Controls, Bldg 7988 | 45,108 | 4,028 | 0 | 0 | 0 | 4,028 | 14,400 | 4 |
| LI #21US | New Light System Bldg 7974 | 33,750 | 2,700 | 0 | 0 | 0 | 2,700 | 13,140 | 5 |
| LI #22US | New Light System Bldg 7975 | 33,750 | 2,700 | 0 | 0 | 0 | 2,700 | 13,140 | 5 |
| LI #19US | New Light System Bldg 7971 | 43,750 | 3,500 | 0 | 0 | 0 | 3,500 | 17,100 | 5 |
| LI #23US | New Light System Bldg 7976 | 43,750 | 3,500 | 0 | 0 | 0 | 3,500 | 17,100 | 5 |
| *Totals* | | *822,556* | *69,339* | *5,159* | *55,633* | *2,400* | *127,373* | *167,260* | *2.6* |

Table ES8. ECMs with investments between €20K and €200K and simple payback of less than 10 years.

| ECM # | ECM Description | Electrical Savings | | Thermal | | Maintenance €/Yr | Total Savings: Electrical Use, Elec Demand, Thermal, and Maint €/Yr | Investment € | Simple Payback yrs |
|---|---|---|---|---|---|---|---|---|---|
| | | KWh/yr | €/Yr | MMBtu/Yr | €/Yr | | | | |
| CEP #4CO | Substation Optimization, Coleman Barracks | 136,080 | 27,216 | 0 | 0 | 0 | 27,216 | 45,000 | 2 |
| MUL #4 | Optimize Compressed Air Use and Compressor Size Bldg 7902 at Germersheim and Bldg 4 at Coleman Barracks | 175,000 | 15,628 | 0 | 0 | 0 | 15,628 | 40,000 | 3 |
| RAD #4KS | Radiant Heating Katterbach Barracks Bldg 5807 | 0 | 0 | 1,270 | 31,248 | 0 | 31,248 | 129,000 | 4 |
| LI #9CO | Change Bulbs in Exit Lights | 34,950 | 3,121 | 0 | 0 | 4,800 | 7,921 | 36,000 | 5 |
| LI #17US | New Lighting System, Bldg 7902 | 112,000 | 10,002 | 0 | 0 | 1,200 | 11,202 | 62,400 | 6 |
| DIN #1CA | Utilize Kitchen Hood Control, Bldg 112 | 26,630 | 2,378 | 458 | 4,938 | 0 | 7,316 | 42,200 | 6 |
| DIN #2CO | Modify Kitchen Hoods with End Skirts and Temperature Controlled Exhaust, Bldg 45 | 25,400 | 3,629 | 240 | 2,588 | 0 | 6,217 | 40,600 | 7 |
| RAD #1KS | Radiant Heating Katterbach Barracks Bldg 5801 | 0 | 0 | 519 | 12,768 | 0 | 12,768 | 103,000 | 8 |
| LI #14US | Use Occupancy Sensors to Turn off Lights, Bldg 7951 and 7971 | 35,583 | 3,178 | 0 | 0 | 0 | 3,178 | 27,000 | 8 |
| RAD #8KS | Radiant Heating Storch Barracks Bldg 6633 | 0 | 0 | 457 | 11,256 | 0 | 11,256 | 102,000 | 9 |
| *Totals* | | *545,643* | *65,151* | *2,944* | *62,798* | *6,000* | *133,949* | *627,200* | *4.7* |

Table ES9. ECMs requiring investment > $200K and simple payback <= 10 years.

| ECM # | ECM Description | Electrical Savings | | Thermal | | Maintenance €/yr | Total Savings: Electrical Use, Elec Demand, Thermal, and Maint €/yr | Investment € | Simple Payback yrs |
|---|---|---|---|---|---|---|---|---|---|
| | | KWh/yr | €/yr | MMBtu/yr | €/yr | | | | |
| RAD #7KS | Radiant Heating Storch Barracks, Bldg 6502 | 0 | 0 | 1,464 | 36,036 | 0 | 36,036 | 268,000 | 7 |
| RAD #5KS | Radiant Heating Storch Barracks, Bldg 6500 | 0 | 0 | 1,461 | 35,952 | 0 | 35,952 | 268,000 | 7 |
| RAD #6KS | Radiant Heating Storch Barracks, Bldg 6501 | 0 | 0 | 1,239 | 30,492 | 0 | 30,492 | 268,000 | 9 |
| REN #23US | Install a Wind Mill at Germersheim | 3,000,000 | 267,900 | 0 | 0 | -45,000 | 222,900 | 2,000,000 | 9 |
| LI #18US | New Lighting System, Bldg 7987, 7988 and 7989 | 507,000 | 45,275 | 0 | 0 | 1,700 | 46,975 | 448,000 | 10 |
| REN #2CO | PV System, Bldg 11 Coleman Barracks, Manheim | 44,744 | 20,107 | 0 | 0 | 0 | 20,107 | 201,297 | 10 |
| REN #3CO | PV System, Bldg 13 Coleman Barracks, Manheim | 44,744 | 20,107 | 0 | 0 | 0 | 20,107 | 201,297 | 10 |
| REN #4CO | PV System, Bldg 15 Coleman Barracks, Manheim | 44,744 | 20,107 | 0 | 0 | 0 | 20,107 | 201,297 | 10 |
| REN #5CO | PV System, Bldg 17 Coleman Barracks, Manheim | 44,744 | 20,107 | 0 | 0 | 0 | 20,107 | 201,297 | 10 |
| REN #6CO | PV System, Bldg 29 Coleman Barracks, Manheim | 44,744 | 20,107 | 0 | 0 | 0 | 20,107 | 201,297 | 10 |
| REN #7CO | PV System, Bldg 31 Coleman Barracks, Manheim | 44,744 | 20,107 | 0 | 0 | 0 | 20,107 | 201,297 | 10 |
| REN #8CO | PV System, Bldg 33 Coleman Barracks, Manheim | 44,744 | 20,107 | 0 | 0 | 0 | 20,107 | 201,297 | 10 |
| REN #9CO | PV System, Bldg 35 Coleman Barracks, Manheim | 44,744 | 20,107 | 0 | 0 | 0 | 20,107 | 201,297 | 10 |
| REN #19KS | PV System, Bldg 651, Storch Barracks, Illesheim | 63,262 | 28,148 | 0 | 0 | 0 | 28,148 | 285,443 | 10 |
| REN #28US | Photovoltaics, Bldg 7826, U.S. Depot Germersheim | 62,229 | 27,688 | 0 | 0 | 0 | 27,688 | 285,443 | 10 |
| REN #12KS | PV System, Bldg 5819, Katterbach Barracks, Ansbach | 52,123 | 23,292 | 0 | 0 | 0 | 23,292 | 241,529 | 10 |
| REN #11KS | PV System, Bldg 5810, Katterbach Barracks, Ansbach | 53,650 | 23,955 | 0 | 0 | 0 | 23,955 | 248,848 | 10 |
| REN #27US | Photovoltaics, Bldg 7846, U.S. Depot Germersheim | 54,931 | 24,508 | 0 | 0 | 0 | 24,508 | 256,167 | 10 |
| REN #24US | Photovoltaics, Bldg 7889, U.S. Depot Germersheim | 46,503 | 20,843 | 0 | 0 | 0 | 20,843 | 218,208 | 10 |
| *Totals* | | *4,197,650* | *622,465* | *4,164* | *102,480* | *-43,300* | *681,645* | *6,398,014* | *9.4* |

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# Preface

The Installation Management Command (IMCOM) funded an Annex 46 energy assessment initiative to visit various Army installations to identify and initiate energy-related projects that could enable the installations to better meet the energy reduction requirements mandated by Executive Order 13123, Energy Policy Act (EPAct) 1992 and EPAct 2005. One of the initiative's most important goals is to assist the installations in not only determining the projects, but also in determining applicable funding and execution methods. This study was conducted for U.S. Army Garrison (USAG) Heidelberg under the Annex 46 program. The technical monitors were David Yacoub, Installation Management Agency (IMA), Europe Region Engineer Division, and Paul Volkman, Headquarters, Installation Management Command (HQIMCOM).

Previous studies related to this were also conducted at: Fort Stewart, GA; Fort Bliss TX; West Point Military Academy, NY; USAG Vicenza, Italy; and several sites in Germany. The results of those studies are documented separately.

The work was managed and executed by ERDC-CERL. The Energy Team, as funded by IMCOM, is composed of individuals from Construction Engineering Research Laboratory (CERL), Facilities Division (CF), Energy Branch (CF-E). Appreciation is owed to Peter Ahrend Directorate of Public Works (DPW) USAG Heidelberg, David Buffum USAG Mannheim, Daniel Welch DPW USAG Heidelberg, and Uwe Sternberger Engineer Support Division Germersheim. The CERL principal investigators were David Underwood and Alexander Zhivov. The associated Technical Director was Martin J. Savoie, CEERD-CV-T. The Director of ERDC-CERL is Dr. Ilker R. Adiguzel.

CERL is an element of the U.S. Army Engineer Research and Development Center (ERDC), U.S. Army Corps of Engineers. The Commander and Executive Director of ERDC is COL Gary E. Johnston, and the Director of ERDC is Dr. James R. Houston.

# Unit Conversion Factors

| Multiply | By | To Obtain |
|---|---|---|
| Acres | 4,046.873 | square meters |
| British thermal units (BTU, International Table) | 1,055.056 | joules |
| MMBtu | 0.293 | MWh |
| cubic feet | 0.02831685 | cubic meters |
| cubic inches | 1.6387064 E-05 | cubic meters |
| cubic yards | 0.7645549 | cubic meters |
| degrees (angle) | 0.01745329 | radians |
| degrees Fahrenheit | (F-32)/1.8 | degrees Celsius |
| Feet | 0.3048 | meters |
| gallons (U.S. liquid) | 3.785412 E-03 | cubic meters |
| Inches | 0.0254 | meters |
| miles (U.S. statute) | 1,609.347 | meters |
| miles per hour | 0.44704 | meters per second |
| square feet | 0.09290304 | square meters |
| square inches | 6.4516 E-04 | square meters |
| square miles | 2.589998 E+06 | square meters |
| square yards | 0.8361274 | square meters |
| tons (2,000 pounds, mass) | 907.1847 | kilograms |
| tons (2,000 pounds, mass) per square foot | 9,764.856 | kilograms per square meter |
| Yards | 0.9144 | Meters |
| Euros (€) | 0.625 | $U.S. |

# 1 Introduction

## Background

### Campbell Barracks

Campbell Barracks, located in Heidelberg, Germany consists of roughly 62 buildings—mostly barracks and administrative. Campbell Barracks is the location of the Headquarters of the U.S. Army in Europe and Seventh Army Headquarters, U.S. Army, Europe (HQ USAREUR), the V Corps, and NATO's Component Command-Land Headquarters, Heidelberg.

### Coleman Barracks

The caserne is home to numerous 414th Base Support Battalion (BSB) family members. Although there is family housing at Armstrong, most married soldiers assigned to 1-1 Cav "The Blackhawk Squadron" live in the Gelnhausen Community (Coleman Barracks). This community is about 18 km from Hanau and has family housing, a small commissary, and temporary billeting facilities. Most single soldiers live in and around the Budingen community or in neighboring towns.

### Katterbach and Storch Barracks

Located in the heart of Bavaria, the U.S. Army Garrison Ansbach provides base support services to military personnel and their families.

### U.S. Army Depot

This new facility is responsible for the rapid segregation, sorting and consolidation of multiple consignee shipments from a range of sources and delivery to the customer. It is a component of the Defense Logistic Agency's Defense Distribution Center and supports all Defense Department activities in Europe.

## Objectives

The objectives of this study were to identify energy inefficiencies and wastes at Campbell Barracks – Heidelberg, Coleman Barracks – Manheim, Katterbach Barracks – Ansbach, Storch Barracks – Illesheim, and U.S. Depot – Germersheim, and to propose energy-related projects with applicable funding and execution methods that could enable the installations to better meet the energy reduction requirements mandated by Executive Order 13123 and EPAct 2005.

## EEAP project team and summary of activities

### ERDC-CERL

ERDC/CERL implemented an Energy Assessment methodology that was previously developed as part of the "Industrial Process Modeling and Optimization" program under the auspices of the IEA ECBCS Programme Annex 46 "Holistic Assessment Toolkit on Energy Efficient Retrofit Measures for Government Buildings (EnERGo)." The protocol is designed to assist energy managers and Regional Energy Managers to develop energy conservation projects (self-help for energy managers).

### Private contractors

Private contractors with various technical areas of expertise were a vital part of the Energy Team. Since Campbell Barracks – Heidelberg, Coleman Barracks – Manheim, Katterbach Barracks – Ansbach, Storch Barracks – Illesheim, and U.S. Depot – Germersheim all have interests in developing renewable projects, an expert on renewables such as photovoltaic electricity generation was brought into the team. Additionally, other experts in heating, ventilating, and air-conditioning (HVAC), building envelope, central heating systems, and lighting rounded out the contractor portion of the team.

## Approach

### Energy assessment protocol

This study was conducted using an Energy Assessment Protocol developed by CERL in collaboration with a team of government, institutional, and private sector parties as a part of the IEA ECBCS Program Annex 46.* This protocol is based on the analysis of information available from the literature, training materials, the documented and non-documented practical

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*More information is available through the Annex 46 website, URL: http://www.annex46.org/

experiences of contributors, and previous successful showcase energy assessments conducted by a diverse team of experts at the U.S. Army facilities.

The Energy Assessment Protocol addresses technical and non-technical organizational capabilities required to make a successful assessment geared to identifying energy and other operating costs reduction measures without adversely impacting Indoor Air Quality, product quality, or (in the case of repair facilities) safety and morale.

A critical element for energy assessment is a capability to apply a “holistic” approach to the energy sources and sinks in the audited target (installation, building, system, and their elements). The holistic approach suggested by the protocol includes the analysis of opportunities related to the energy generation process and distribution systems, building envelope, lighting, internal loads, HVAC, and other mechanical and energy systems. The Sankey diagram (Figures 1 and 2) illustrates a useful way of visualizing the energy flows within a facility or process.

The Protocol addresses several different scopes (building stock, individual building, system, and component) and levels of assessment. It distinguishes between the pre-assessment phase (Level 0: selection of objects for Energy Assessments and required composition of the audit team) and three levels of energy audits with differing degrees of rigor. Each of these three levels may be implemented in different ways, involving simplified or more detailed assessments, depending on the availability of energy consumption information and other data.

During the selection phase, one can choose, from a building stock, those facilities that have the most promising energy saving potential. Similarly, one can select, from a specific building, the systems to be audited or, from a system, the components to be considered for more detailed analysis.

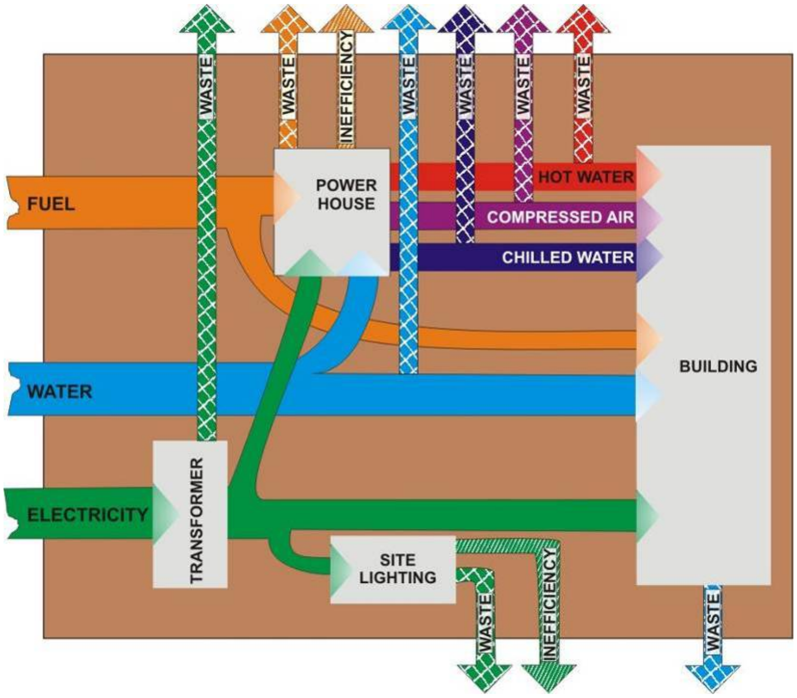


Figure 1. Example Sankey diagram of energy usage, waste, and inefficiencies for an Army installation.

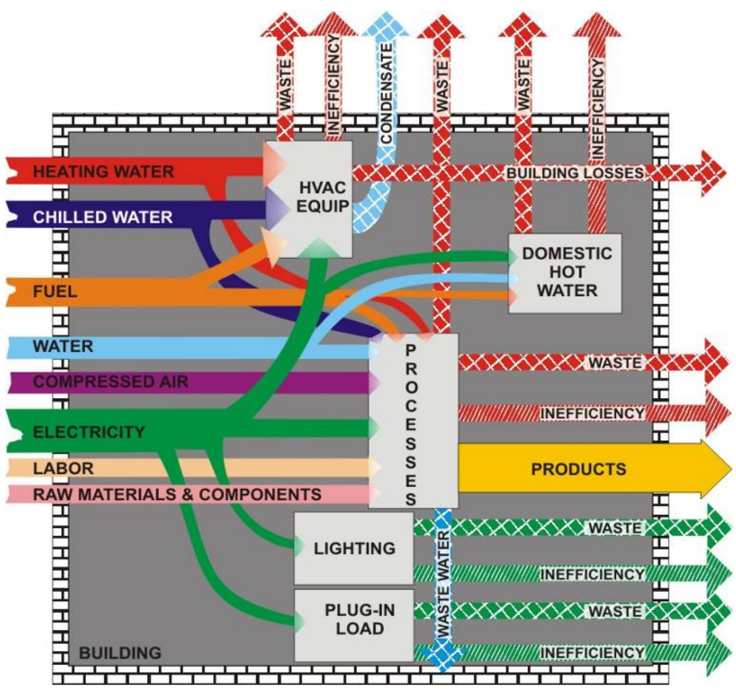


Figure 2. Example Sankey diagram of energy usage, waste, and inefficiencies for a building with production process.

The scope and depth of the assessments differ in their objectives, methodologies, procedures, required instrumentation, and approximate duration (Figure 3).

*Level I audit*

A Level I audit (qualitative analysis) is a preliminary energy and process optimization opportunity analysis consisting primarily of a walk-through review to analyze and benchmark existing documents and consumption figures. The Level I audit takes from 2 to 5 days, and identifies the bottom-line dollar potential of energy conservation and process improvements. No engineering measurements using test instrumentation are made. If the consumption figures are not available (e.g., due to the absence of metering), which is typical for many industrial facilities and manufacturing processes, the Level I audit can be based on analyses and estimates by experienced auditors.

Figure 3. Scope and depth of Levels 0–III assessments.

A Level I audit would normally recommend that the installation perform some metering, which could be followed by a Level II audit to verify the Level I assumptions, and to more fully develop the ideas from the Level I screening analysis.

#### *Level II audit*

A Level II audit (quantitative analysis) includes an analysis geared towards funds appropriation; this analysis uses calculated savings and partial instrumentation measurements with a cursory level of analysis. The Level II study typically takes 5 to 10 times the effort of a Level I, and could be accomplished over a 2- to 6-month period, depending on the scope of the effort. The Level II effort includes an in-depth analysis in which the most crucial assumptions are verified. The end product will be a group of “appropriation grade” energy and process improvement projects for funding and implementation.

#### *Level III audit*

Finally, the Level III audit (continuous commissioning) is a detailed engineering analysis with implementation, performance measurement and verification (M&V) assessment, and fully instrumented diagnostic measurements (long term measurements). This level takes 3 to 18 months to accomplish. For Energy Savings Performance Contract (ESPC) projects, the Level III audit is prolonged until the end of the contract to guarantee that all installed systems and their components operate correctly over their useful lifetimes.

### Keys to a successful audit

The key elements that guarantee success of the Energy Assessment are:

- Involvement of key facility personnel and their on-site contractors who know what the major problems are, where they are, and have already thought of many potential solutions;
- The facility personnel’s sense of “ownership” of the ideas, which encourages a commitment to successful implementation; and
- A focus on site-specific, critical cost issues. If solved, the greatest possible economic contribution to a facility’s bottom line will be realized. Major potential cost issues can include: facility use (bottlenecks), mission, labor (productivity, planning, and scheduling), energy (steam,

electricity, compressed air), waste (air, water, solid, hazardous), equipment (outdated or state-of-the-art).

From a strictly cost perspective, production measures such as process capacity and labor use/productivity, along with soldiers' well-being can be far more significant than energy and environmental concerns. All of these issues, however, must be considered together to accomplish the facility's mission in the most efficient and cost-effective way.

### General overall process

The overall process is comprised of the following steps:

1. Make an initial site visit to among other items determine the Site's major energy issues and familiarize the Engineering Energy Analysis Program (EEAP) team with installation and operations.
2. Assemble a team of SMEs with expertise in technical areas relating to those identified in the initial site visit.
3. Make a technical assessment visit with the SMEs to make building specific Energy Conservation Measure (ECM) evaluations.
4. Analyze findings and developed implementation strategies.

## Scope

The scope of this Annex 46 Energy Optimization Assessment included a Level I study of central energy plants and associated steam distribution systems administration facilities and systems (HVAC, Lighting, Building Envelope, etc.), warehouses and small repair shops (HVAC, Lighting, Building Envelope, etc.), Renewables (Photovoltaic, solar heating, wind), and Radiant Heating.

## Mode of technology transfer

The results of this work will be presented to IMCOM, ACSIM and Campbell Barracks – Heidelberg, Coleman Barracks – Manheim, Katterbach Barracks – Ansbach, Storch Barracks – Illesheim, and U.S. Depot – Germersheim for their consideration for implementation and funding and as the basis for other currently conducted studies related to planning for a new central energy plant and use of renewable energy sources.

It is anticipated that the results of this work will contribute to an enhanced awareness within the Installation Management Command (IMCOM), the U.S. Army Corps of Engineers and its districts, and other Army organizations of opportunities to improve the overall energy efficiency of Army installations. Additionally, this information will be disseminated via workshops, presentations, and professional industrial energy technology conferences.

# 2 Installation Energy Use Rates and Historic Use

As reported by U.S. Army Garrison (USAG) Heidelberg, the installations under this Garrison had the energy use and associated costs for the years 2005 through 2007 as shown and listed in Figures 4–6 and Tables 1–3. At the time of this audit, the USAG Heidelberg Directorate of Public Works (DPW) gave the following costs to be used in the analysis as the most realistic costs for future energy costs:

- Electricity = €0.0893/KWh
- Fuel Oil = €10.78/million BTU.

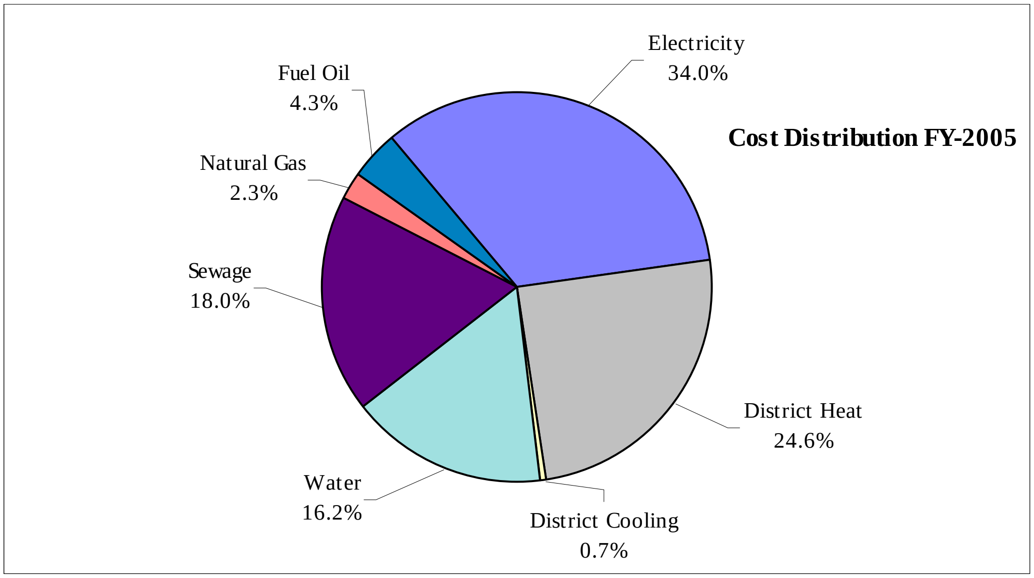


Figure 4. USAG Heidelberg — FY05 energy and water cost.

Table 1. USAG Heidelberg — FY05 energy and water cost.

| | Consumption | | Cost | Average Cost Per Unit | Unit Cost Comp. to Prev. Year |
|---|---|---|---|---|---|
| Electricity | 83,759,237 | kWh | €5,235,065.36 | 0.0625013 | 19.92% |
| District Heat | 92,265.065 | MWh | €3,786,889.05 | 41.0435851 | 3.18% |
| District Cooling | 3,785,835 | MWh | €103,575.60 | 27.3587201 | -3.79% |
| Water | 1,232,060 | m³ | €2,498,892.61 | 2.0282231 | 6.49% |
| Sewage | 971,922 | m³ | €2,772,102.57 | 2.8521863 | 76.54% |
| Natural Gas | 9,932,925 | kWh | €348,678.66 | 0.0351033 | 20.35% |
| Fuel Oil | 2,176,327 | L | €654,651.76 | 0.3008058 | 44.25% |
| *Total Cost:* | | | *€15,399,855.61* | | *23.37%* |
| Total SF: | | | 11,587,763 | SF | |
| Cost by SF: | | | 1.328976 | €/SF | |
| Dollar Rate: €1.0314 /$1 | | | | | |

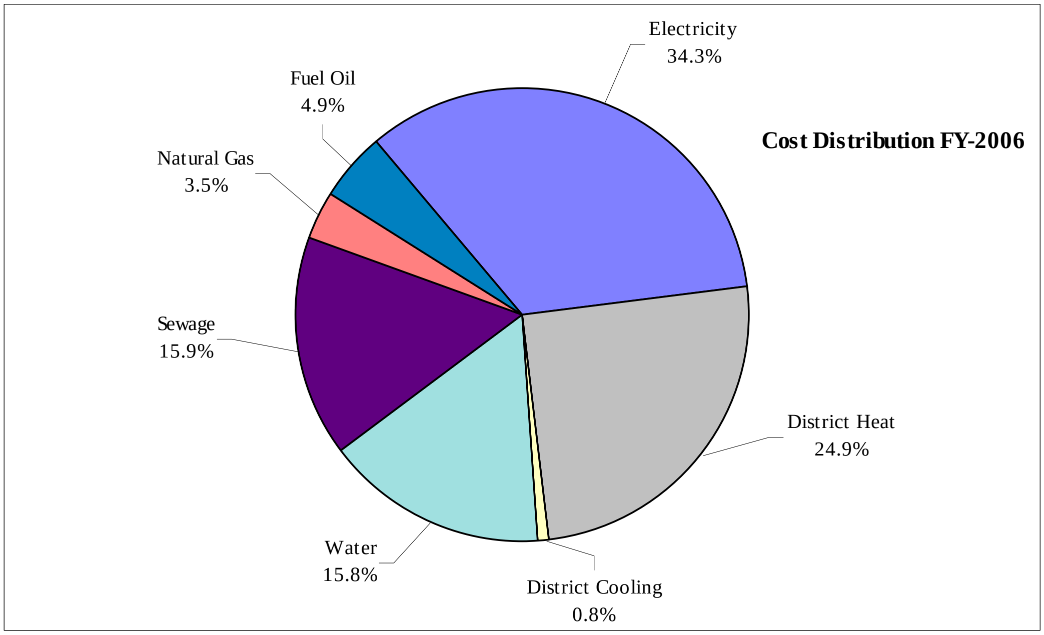


Figure 5. USAG Heidelberg — FY06 energy and water cost.

Table 2. USAG Heidelberg — FY06 energy and water cost.

| | Consumption | | Cost | Average Cost Per Unit | Unit Cost Comp. to Prev. Year |
|---|---|---|---|---|---|
| Electricity | 81,907,989 | kWh | €5,417,195.48 | 0.0661376 | 5.82% |
| District Heat | 91,152,130 | MWh | €3,933,243.82 | 43.1503227 | 5.13% |
| District Cooling | 4,059,953 | MWh | €128,935.72 | 31.7579339 | 16.08% |
| Water | 1,294,277 | m³ | €2,494,387.96 | 1.9272443 | -4.98% |
| Sewage | 954,803 | m³ | €2,506,822.15 | 2.6254864 | -7.95% |
| Natural Gas | 12,258,992 | kWh | €545,467.82 | 0.0444953 | 26.76% |
| Fuel Oil | 1,880,310 | Liter | €770,276.14 | 0.4096538 | 36.19% |
| *Total Cost:* | | | *€15,796,329.09* | | *2.57%* |
| Total SF: | | | 10,874,004 | SF | |
| Cost by SF: | | | 1.452669 | €/SF | |
| Dollar Rate: €0.8785 /$1 | | | | | |

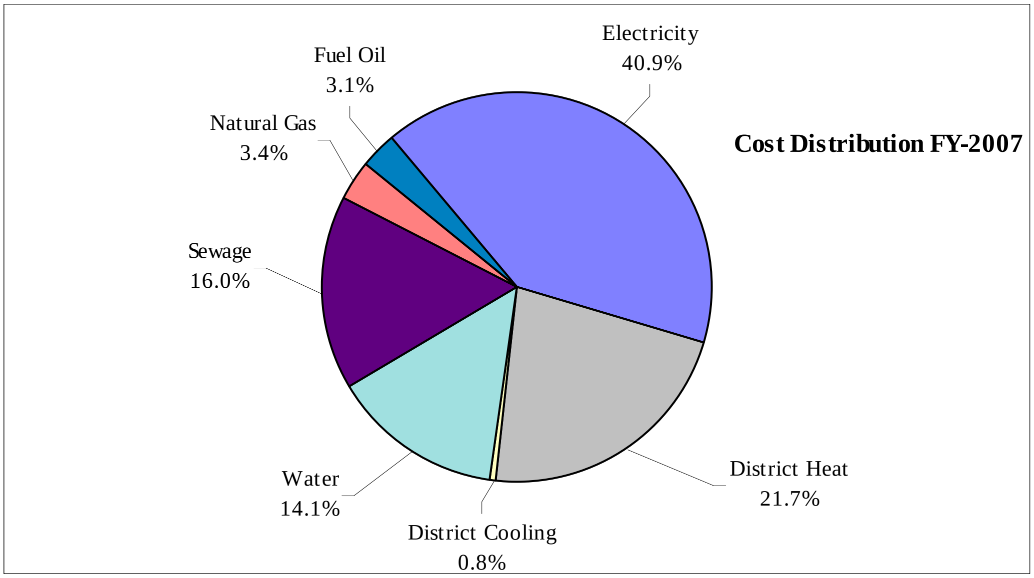


Figure 6. USAG Heidelberg — FY07 energy and water cost.

Table 3. USAG Heidelberg — FY07 energy and water cost.

| | Consumption | | Cost | Average Cost Per Unit | Unit Cost Comp. to Prev. Year |
|---|---|---|---|---|---|
| Electricity | 81,566,143 | kWh | €6,870,368.96 | 0.0842306 | 27.36% |
| District Heat | 75,606,459 | MWh | €3,642,233.67 | 48.1735783 | 11.64% |
| District Cooling | 3,978,141 | MWh | €133,206.97 | 33.4847273 | 5.44% |
| Water | 1,226,430 | m³ | €2,358,612.86 | 1.9231533 | -0.21% |
| Sewage | 900,787 | m³ | €2,686,511.34 | 2.9824047 | 13.59% |
| Natural Gas | 11,589,470 | kWh | €576,104.15 | 0.0497093 | 11.72% |
| Fuel Oil | 1,401,254 | Liter | €511,803.18 | 0.3652465 | -10.84% |
| *Total Cost:* | | | *€16,778,841.12* | | *6.22%* |
| Total SF: | | | 10,758,680 | SF | |
| Cost by SF: | | | 1.559563 | €/SF | |

# 3 Photovoltaics — Background, Technology Description, and Analysis Methodology

## Photovoltaic systems background and preliminary analysis

The following basic factors were defined to ensure reliable results from the evaluations:

- For the selection of roofs with sufficient solar potential, the best range of orientation and the best range of inclination was defined with a simulation based on a standard Photovoltaic (PV)-System.
- The technology and the supplier with the most efficient products were selected.
- The legal and fiscal aspects were checked.
- The basic calculation factors were calculated by using an example building for which the selected supplier delivered an orientation quotation.

## Available photovoltaic technologies

There are many suppliers of photovoltaic PV Modules, which employ different technologies. Because the efficiency and the quality of the PV Modules will significantly impact their profitability over a 20-yr period, the efficiency of the various technologies must first be explored.

### Comparison of temperature coefficient

The first selection criterion of the PV module technology is the power generation against the temperature coefficient. Figure 7 shows that the copper indium diselenide (CIS) technology is more efficient than the Mono- and Polysilicon technologies in both 50 °C and 75 °C temperature ranges.

The results of the Benchmark 1 tests done over a 2-yr period (Figure 8) show that, of the three technologies, the CIS technology shows the best energy generating performance, especially under conditions of partial shadow due to snow or other comparable obstacles.

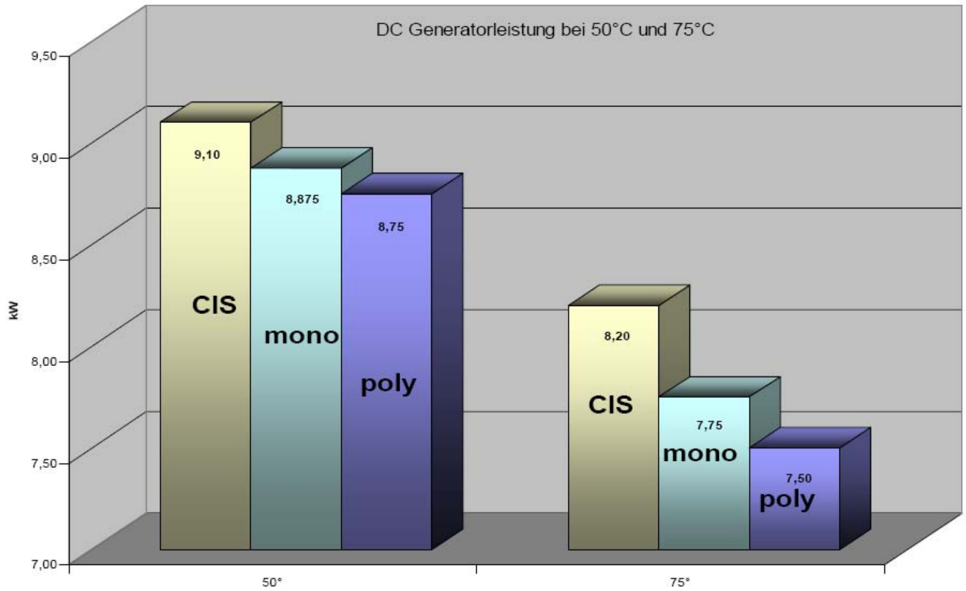


Figure 7. Comparison of temperature coefficient.

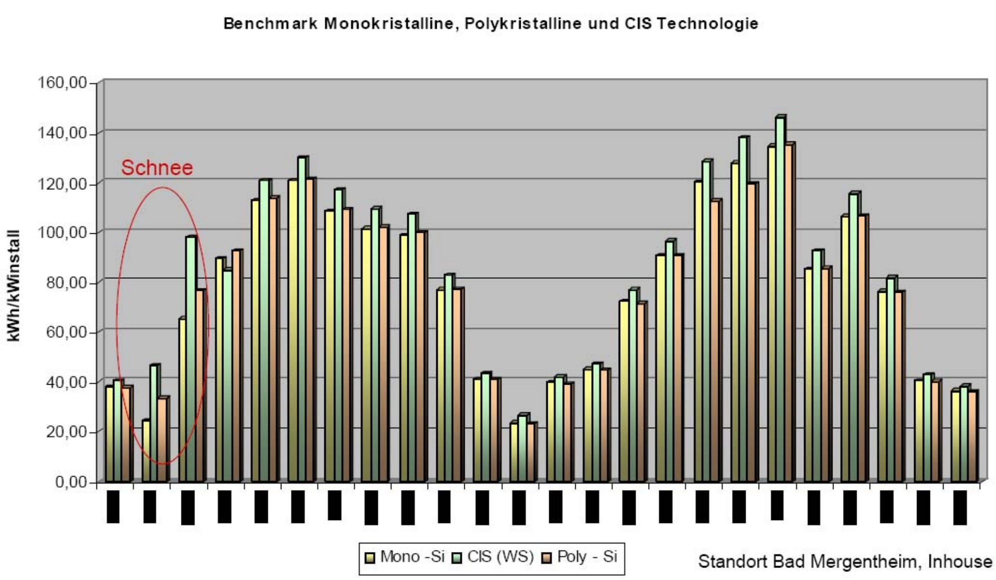


Figure 8. Benchmark 1 – photovoltaic technologies.

Benchmark 2 tests compared comparable PV-Systems installed in Cyprus and Germany based on the three mentioned technologies and delivered from different suppliers: Sanyo (Monosilicon), SunPower (Monosilicon) and Würth Solar (CIS) (Figure 9).

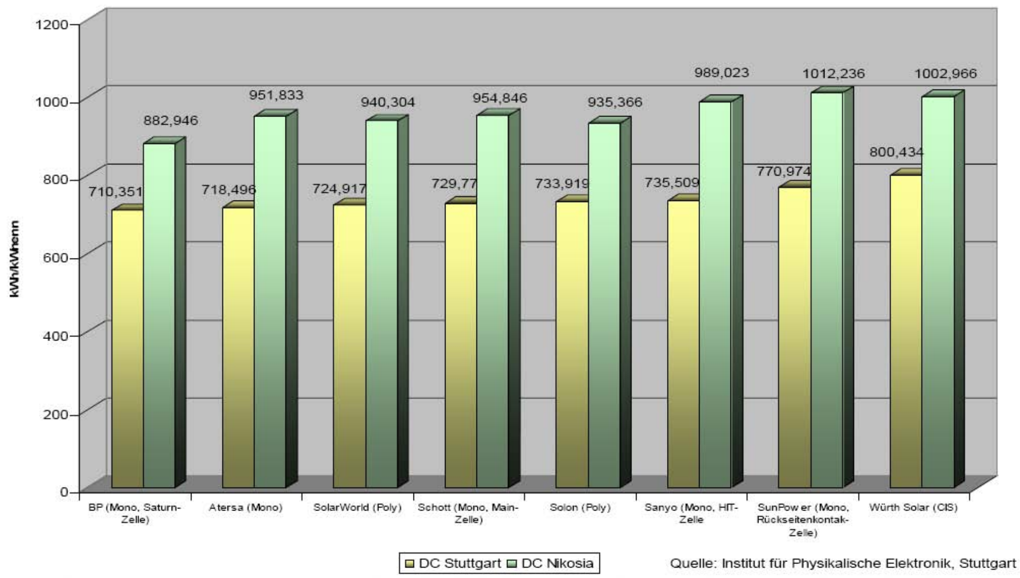


Figure 9. Benchmark 2 – photovoltaic technologies.

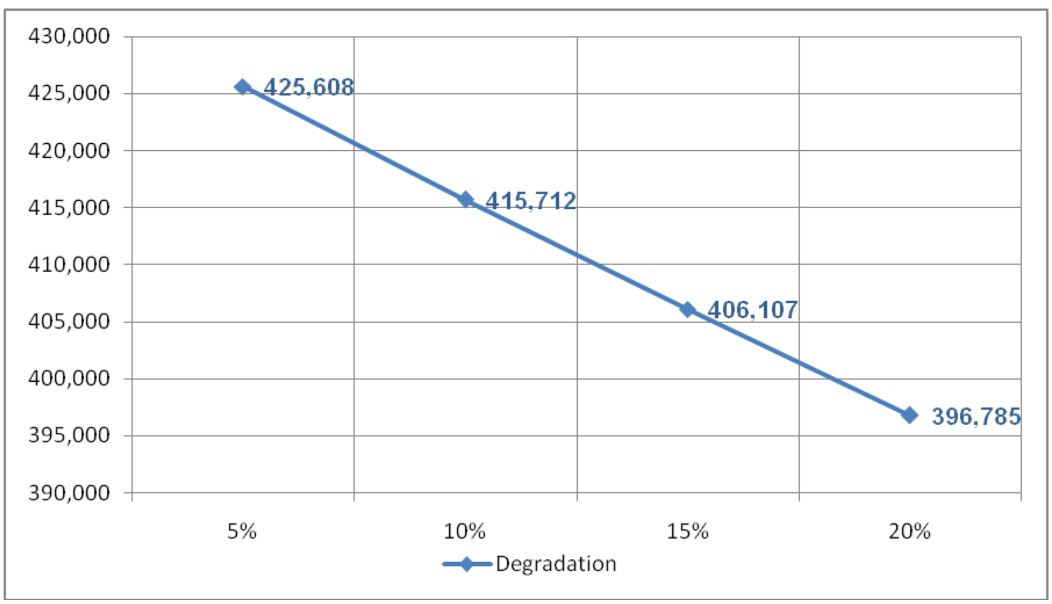


Figure 10. Degradation over 20-yr period.

A measure of the PV-Systems' "degradation values" can show their efficiency losses over the 20-yr period (Figure 10). Significant differences between the various modules are mostly due to the technical construction and the technology of the cells. Although no supplier can deliver reliable data over the past 20 yrs, due to the construction of the modules, intensive tests, and the cell technology, the Würth Solar module promises to have the lowest degradation value over the 20-yr period.

### Technology – conclusion and recommendation

The Würth Solar modules are recommended to be used in the PV-Systems for the following reasons:

- The experience of the PV-market in Germany shows that the Würth PV-Systems are 5 – 10 percent more expensive than PV-Systems from other suppliers, but are also 7 – 10 percent more efficient that PV-Systems from other suppliers.
- The size of the modules allow a better coverage of the roof than other modules
- The power generation efficiency is at the top of the benchmarks.
- The degradation factor of the CIS technology and the Würth Solar modules is lower than at other module types.
- The temperature coefficient is better than at other modules This will be important especially for the southern countries of Europe.
- The glass/glass combination has a higher weather resistance than the normal module construction

As a result of this evaluation, Würth Solar was asked to deliver an orientation quotation for a example building that can be used to define calculation factors for all other buildings/roofs. The values used in the orientation quotation were taken from the detailed calculations received from Würth Solar. It is anticipated that, if PV technology is selected for installation, purchase negotiations certainly will further lower the prices. Figures 11 and 12 show example roof installations of PV modules.

## Simulation of orientation and inclination

The annual results of a simulation of a PV-Systems installation will depend on the roof's orientation (azimuth) and inclination (tilt angle). These basic decision criteria can be used to check the various types of roofs that might be appropriate for a PV-Systems installation, and in determining the roof selection criteria for the recommendations on which roofs or areas in the Garrisons should be use as carrier of PV Systems.

Figure 11. Example flat-roof-installation.

Figure 12. Example ridge-roof installation.

To get comparable results, a typical PV-System was designed based on 50 PV-Modules with approximately 11.5 kW peak. The simulations use the meteorological data of the different locations to see the differences of the yearly results against the location data (Figures 13 and 14).

### Layout of the simulation PV system

| | |
|---|---|
| No./Type of Modules: | 50/BP Solar – BP 3230M/230 W |
| No./Type Converter: | 2/SMA – Sunny Boy 6000U/5.9 kW |
| Circuitry: | 2 strings/13 modules/1 converter |
| | 2 strings/12 modules/1 converter |

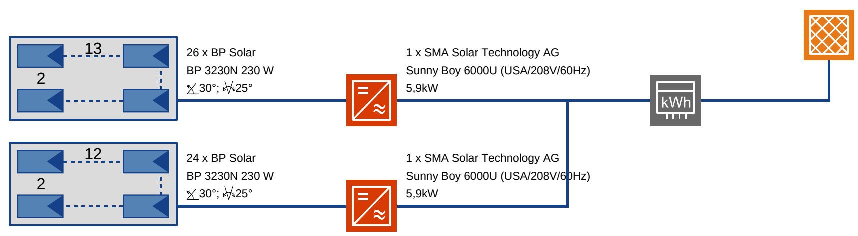


Figure 13. Simulation PV-system layout.

### Sun positions during the year

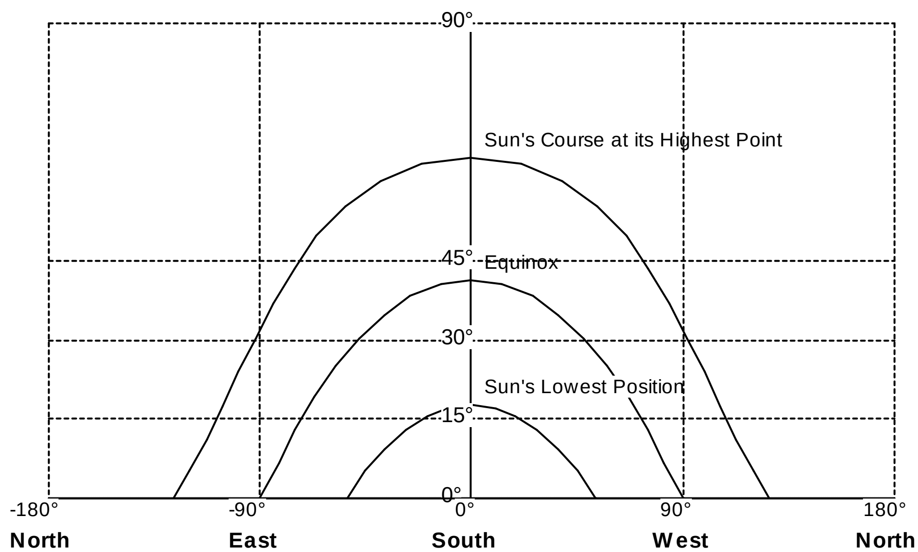


Figure 14. Orientation – sun positions.

Proper positioning of PV-Systems is related to the sun's position during the day and throughout the year. The most effective orientation is directly South (180 degrees) and the most effective inclination is approximately 350 degrees for roof-mounted PV-Systems and for 500 degrees for free-standing PV-Systems. The following simulation tests these figures, and the results of the simulation will define acceptable deviations from these optimal points.

### Simulation of the orientation

This simulation of the orientation of a PV-System was undertaken to define the sector of the orientation that can achieve acceptable results. The inclination (tilt angle) is 350 degrees, and the simulation uses the climate data of Ansbach (Nürnberg). Figures 15–17 and Table 4 show the main values and the results of the described PV-System simulation.

| | |
|---|---|
| PV-Array Irradiation: | Yearly irradiation to the PV-System area |
| Grid Feed-in: | Yearly Grid Feed-in |
| Specific Annual Yield: | Yearly Grid Feed-in per kW peak installed |

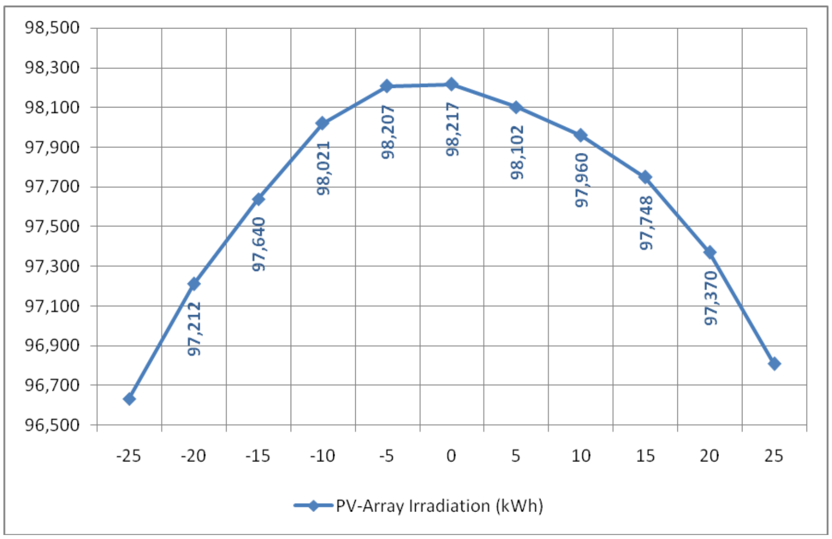


Figure 15. PV-array irradiation (orientation 155 – 205 grad).

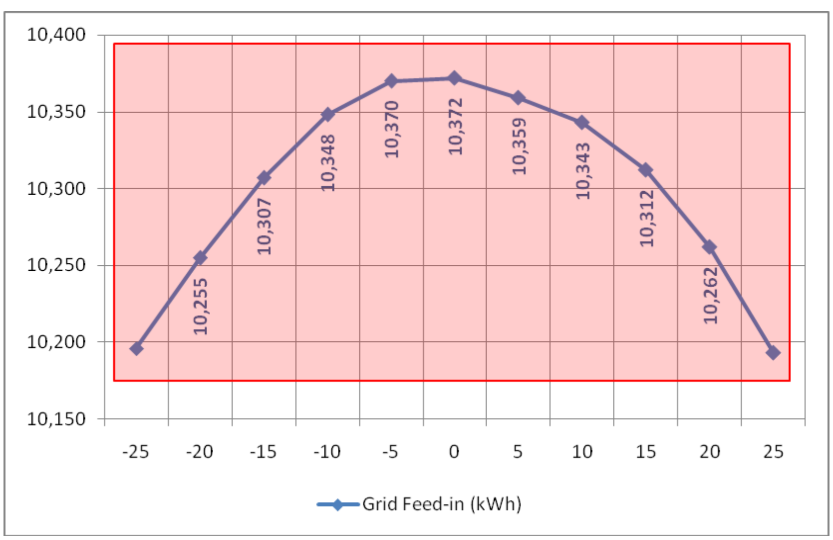


Figure 16. Grid feed-in (orientation 155 – 205 grad).

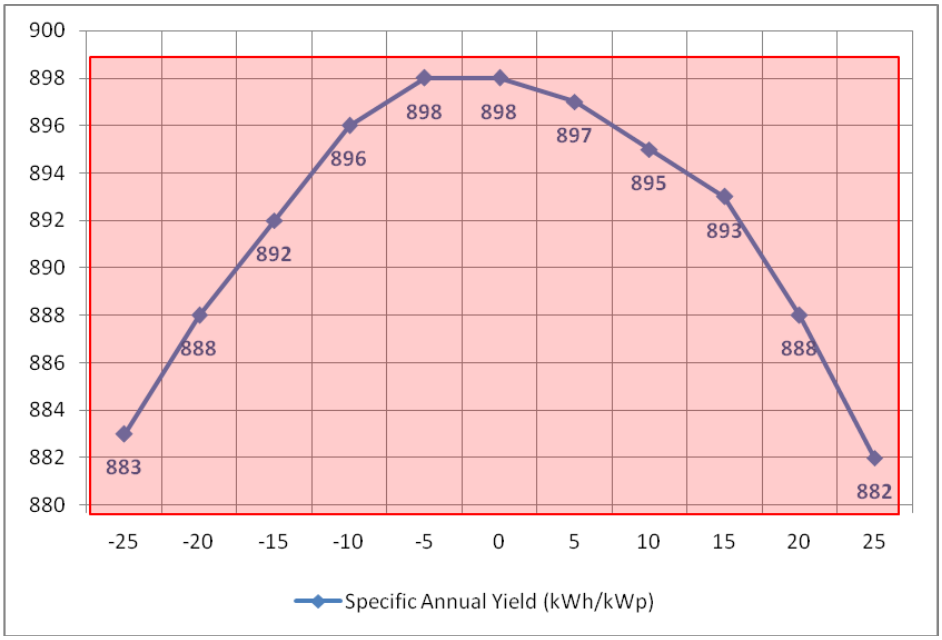


Figure 17. Specific annual yield (orientation 155 – 205 grad).

Table 4. Grid feed-in reduction against orientation/peak = 180 Grad.

| 155 | 160 | 165 | 170 | 175 | 180 | 185 | 190 | 195 | 200 | 205 |
|---|---|---|---|---|---|---|---|---|---|---|
| 98% | 99% | 99% | 100% | 100% | 100% | 100% | 100% | 99% | 99% | 98% |
| 4.767 | 4.794 | 4.819 | 4.838 | 4.848 | 4.849 | 4.843 | 4.835 | 4.821 | 4.797 | 4.765 |
| 883 | 888 | 892 | 896 | 898 | 898 | 897 | 895 | 893 | 888 | 882 |

The results of the simulation show that the orientation of the roof is not a very critical criterion. In the range 155 – 205 degrees, the reduction of the yearly grid feed-in is approximately 2 percent. Then, the first selection criteria is that: All roofs within an orientation range 155 – 205 degrees are applicable for PV-Systems.

## Simulation of the inclination

The second selection criterion is the simulation of the inclination (tilt angle of the roof). Figures 18–20 and Table 5 show the main values and results of the calculated PV-System simulation, with an orientation of 180 degrees, and with the climate data of Ansbach (Nürnberg). In a later stage the differences of the irradiation between the different locations will be shown.

| | |
|---|---|
| PV-Array Irradiation: | Yearly irradiation to the PV-System area |
| Grid Feed-in: | Yearly Grid Feed-in |
| Specific Annual Yield: | Yearly Grid Feed-in per kW peak installed |

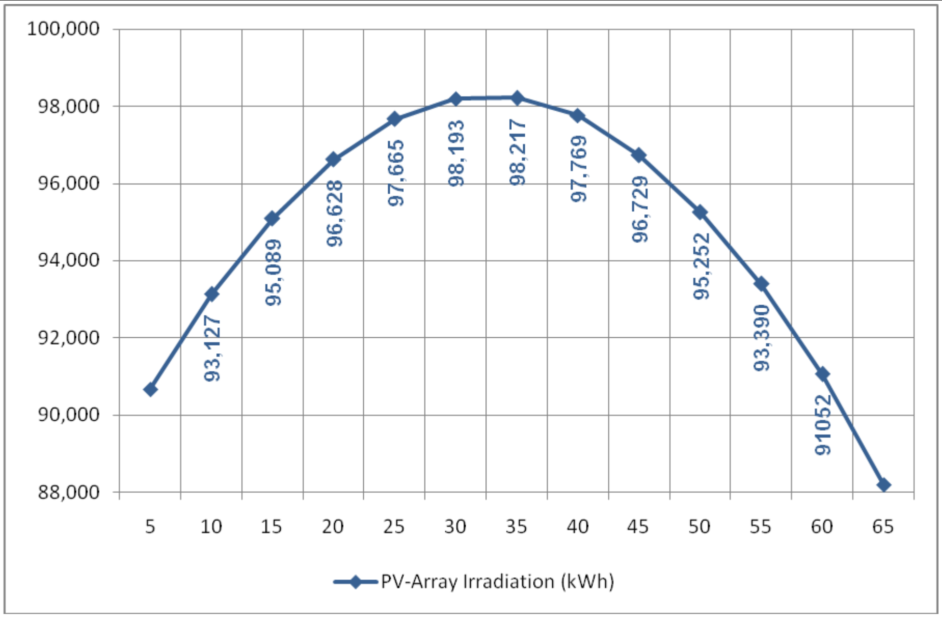


Figure 18. PV-array irradiation (inclination 5 – 65 grad).

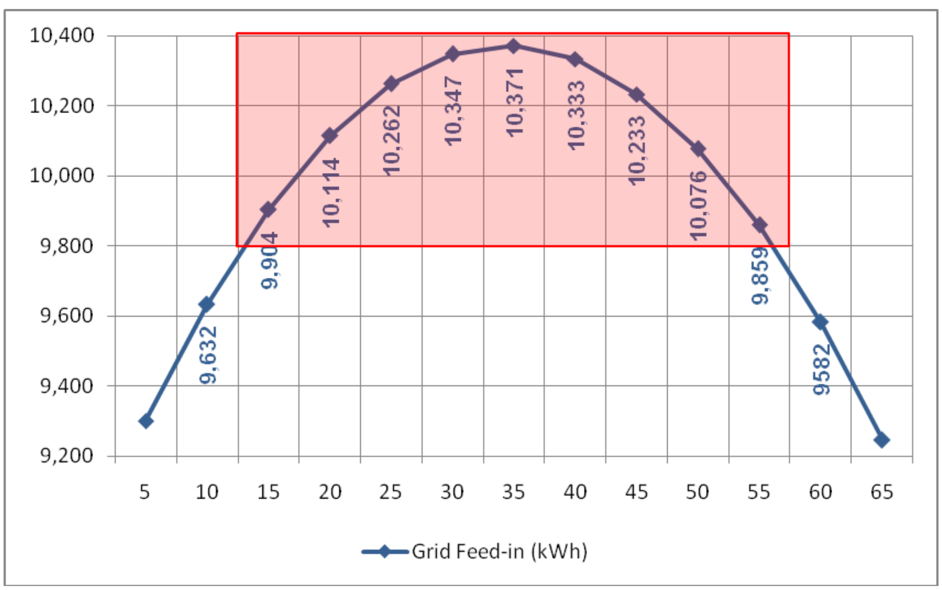


Figure 19. Grid feed-in (inclination 5 – 65 grad).

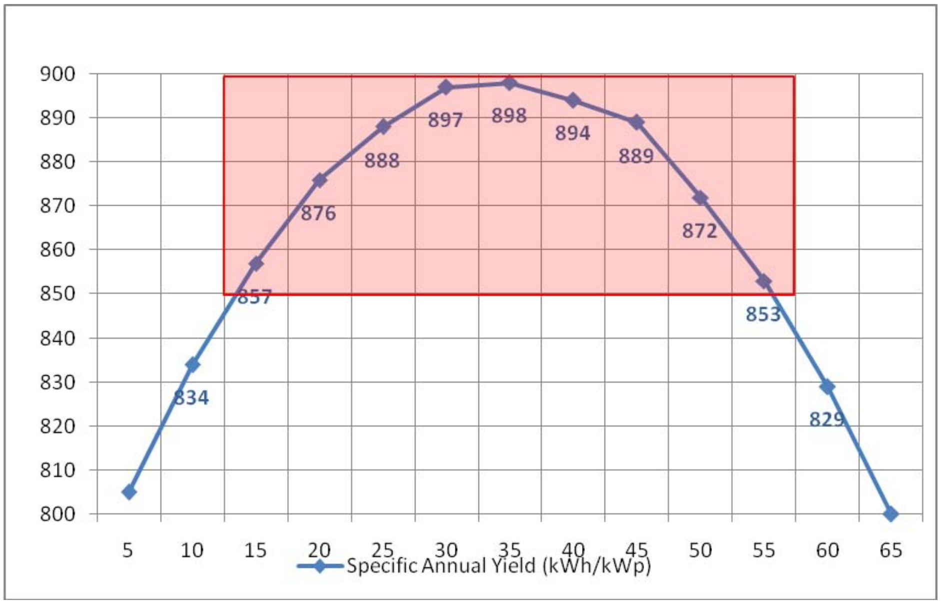


Figure 20. Specific annual yield (inclination 5 – 65 grad).

Table 5. Grid Feed-in reduction against inclination/peak = 35 Grad.

| 3 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 89% | 93% | 96% | 98% | 99% | 100% | 100% | 100% | 99% | 97% | 95% | 92% | 89% |
| 4.347 | 4.502 | 4.630 | 4.728 | 4.797 | 4.837 | 4.848 | 4.830 | 4.783 | 4.710 | 4.609 | 4.479 | 4.322 |
| 805 | 834 | 857 | 876 | 888 | 897 | 898 | 894 | 889 | 872 | 853 | 829 | 800 |

The results of the simulation of the inclination show that the range of the tilt angle acceptable for a reasonable grid feed-in is 150–550 degrees. Below or above this range, the reduction of the grid feed-in is too high (> 5 percent). The second criterion is that: all roofs within an inclination range of 150–550 are applicable for PV-Systems.

## Irradiation, Geographical, Climate, and Funding Data

Figure 21 shows the map locations where the energy assessments were done, and Table lists the irradiation and geographical data of those locations.

The locations in Germany and the Netherlands show comparable yearly grid feed-in results (Figure 22). The yearly grid feed-in of the Belgium location is about 10 percent lower than those in Germany and the Netherlands. By contrast, the Italian location generates approximately 30 percent more than the German locations.

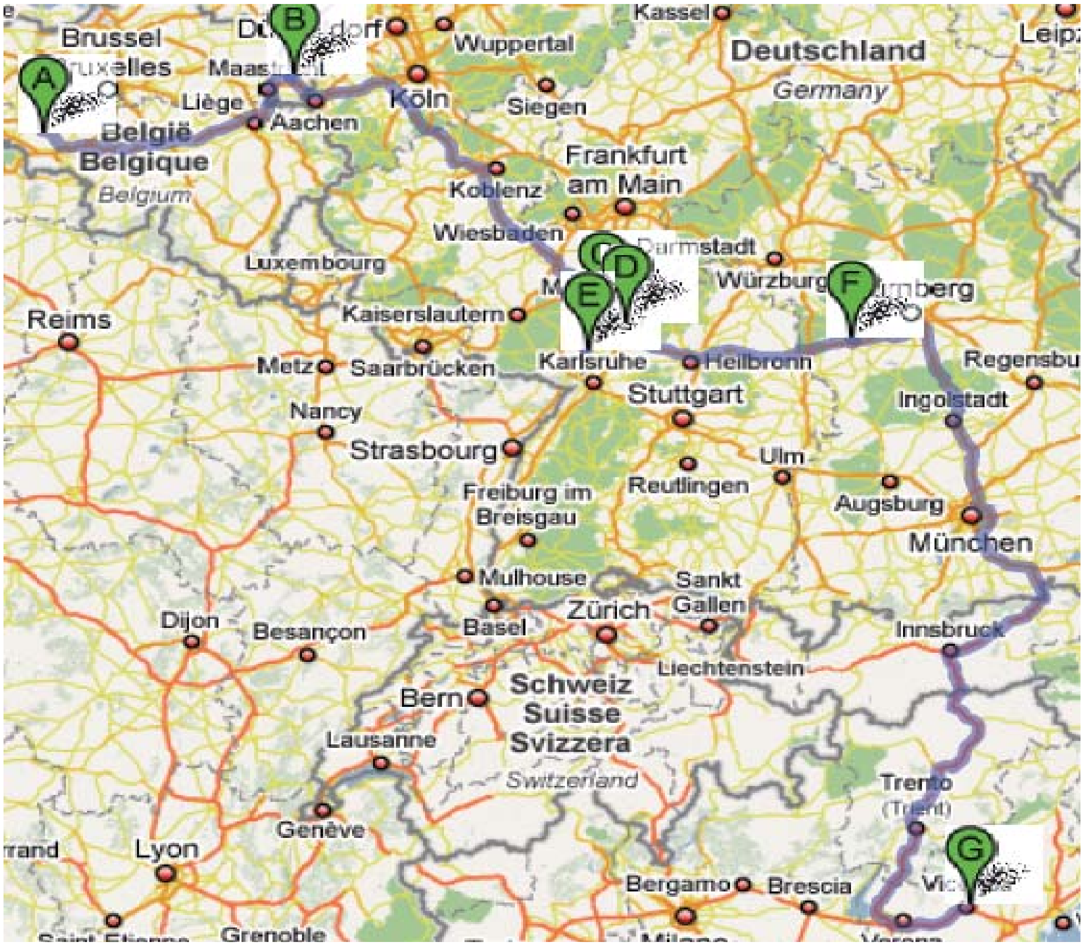


Figure 21. Locations where the energy assessments were done.

Table 6. Irradiation and geographical data of the locations.

| | Location | Annual Irradiation (kWh/m²a) | Longitude/Latitude (0) | Mean outside Temperature (°C) |
|---|---|---|---|---|
| A | Chievres, Belgium | 945 | -3.83/50.57 | 10.2 |
| B | Schinnen, Netherland | 1.010 | -6.07/50.58 | 10.2 |
| C | Mannheim, Germany | 1.065 | -8.55/49.52 | 10.7 |
| D | Heidelberg, Germany | | | |
| E | Germersheim, Germany | | | |
| F | Ansbach/Illesheim, Germany | 1.053 | -11.08/49.50 | 9.2 |
| G | Vicenza, Italy | 1.317 | -11.55/45.55 | 13.3 |

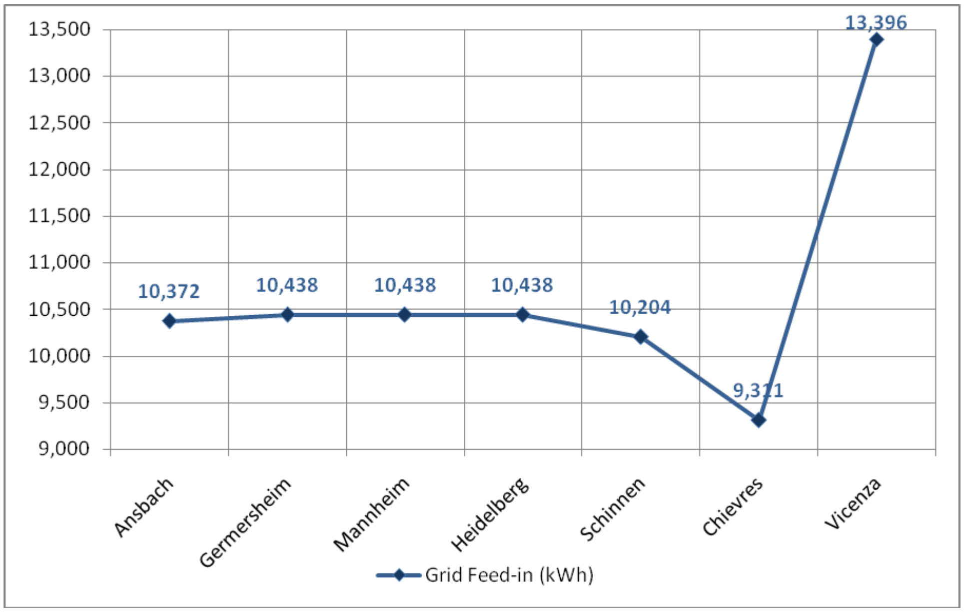


Figure 22. Grid feed-in in different locations.

## Legal aspects and funding regulations

*Grid feed-in funding data*

The profitability of the PV-Systems in the Germany and Italy may be expected. In Belgium and in the Netherlands it is doubtful whether PV-Systems will generate enough electricity to get profitable. Table 7 lists findings for the last criteria for the profitability of PV-Systems.

Table 7. Grid feed-in funding.

| Country | 2007 | 2008 | 2009 |
|---|---|---|---|
| | | *Germany* | |
| 1 – 30 kW | 0.4921 €/kWh | 0.4675 €/kWh | 0.4441 €/kWh |
| 31 – 100 kW | 0.4681 €/kWh | 0.4447 €/kWh | 0.4225 €/kWh |
| > 100 kW | 0.4630 €/kWh | 0.4398 €/kWh | 0.4178 €/kWh |
| | | *Italy* | |
| > 20 kW | Not integrated | Partially integrated | Fully integrated |
| | 0.36 €/kWh | 0.40 €/kWh | 0.44 €/kWh |
| | | *Belgium* | |
| | New regulation in 2008 introduced, mainly for private households. Regulations based on certificates and special funding per region.<br>In case of realization of PV-Systems additional studies are necessary to get the funding. | | |

The detailed calculations for Chievres, Belgium will be calculated using the minimum funding to give an indication what will be needed per kWh to get a profitable PV-System.

*Contracts between U.S. Army and German partners*

To get the funding, a special contract situation must be negotiated. In Mannheim, Coleman Barracks, some PV-Systems are already installed and the relevant agreements between the partners are signed (Table 8). Other Garrisons in Germany may use these agreements as a persuasive precedent.

The Mannheim example may be used as proven practice for all new PV-Systems that may be installed in 2008/2009. IMCOM and Mannheim Garrison agreed together with Oberfinanzdirektion and Bundesvermögensamt that the funding for PV-System generated electricity will go to the local grid-provider (in this case MVV Mannheim). In this case, the funding will lower the electricity invoice.

*Legal situation in Italy*

It is not clear how to proceed in Italy. If a decision is made to implement PV technology, the contract situation to use the existing funds has to be checked.

### PV-system – type of installation

The previous simulations used a roof-mounted PV-System.

Table 8. Contract situation Germany – Mannheim example.

<table>
<tr><td colspan="2">Reduction of Electricity invoice</td><td>IMCOM<br>(Heidelberg/Utilities power procurement) and<br>Garrison Mannheim</td></tr>
<tr><td>MVV<br>Utility Supplier<br>Grid Provider</td><td>Contract Partners</td><td rowspan="3">Procedure agreed between IMCOM and Government organizations<br>Valid for Baden-Württemberg and Rheinlad-Pfalz</td></tr>
<tr><td rowspan="2">Funding</td><td>Oberfinanzdirektion<br>(Financial Office)</td></tr>
<tr><td>Bundesvermögensamt (BIMA)<br>(Real Estate office)</td></tr>
</table>

Figure 23 shows the results of the simulation using a single axis tracking (SAT) and a dual axis tracking (DAT).

The SAT and DAT types of installation are appropriate for use on flat roofs and as free-standing, ground-placed PV-Systems. The improvement of the grid feed-in at peak-situation is compared with roof-mounted PV-Systems significant:

- SAT PV: Systems approximately 30 percent at an inclination of 500
- DAT PV: Systems approximately 34 percent at an inclination of 500.

There is no great difference between the SAT and DAT technologies if the SAT PV-Systems are installed at the optimal inclination. Economic efficiency calculations for the SAT/DAT PV-Systems indicate that one should expect higher investment costs (approximately 10 percent/ 20 percent, respectively) for the mechanical and controlling equipment. Consequently, this report does not consider SAT/DAT PV-Systems. Still, in the open spaces of Ansbach/Illesheim and Chievres, such types of PV-Systems may be considered instead of free-standing PV-Systems.

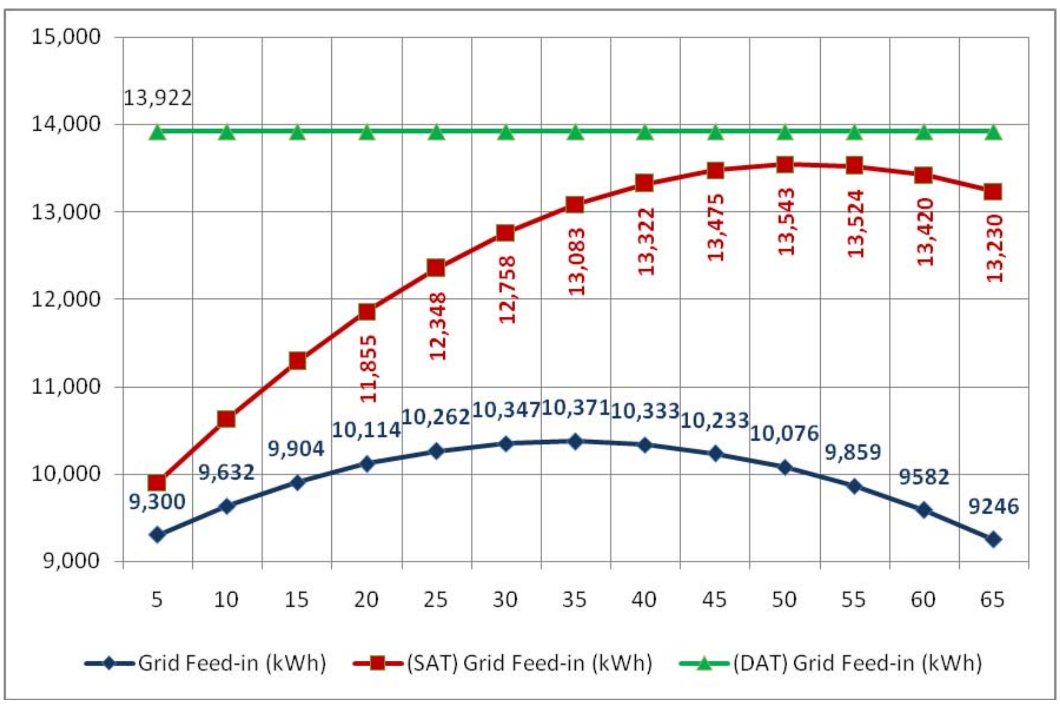


Figure 23. PV-system – type of installation – grid feed-in.

## Example PV-System – Bldg 7889 Germersheim

Bldg 7889 Germersheim (Figure 24) is a warehouse at the U.S.-Depot in Germersheim, Germany. This building was selected because of its orientation and inclination. Although neither the tilt angle of the roof nor its inclination are optimal, this building's roof is typical.

The calculated specific annual yield used by Würth Solar for the Example PV-System was 970 kWh/kWp. An average specific annual yield for the Germersheim area is 1.018 kWh/kWp.* It can be assumed, then, that the values used in the calculations of the Example PV-System are reliable.


Figure 24. Example PV-system – Bldg 7889 Germersheim.

### Overview example PV-system – Bldg 7889 Germersheim

Table 9. Overview example PV-system – Bldg 7889 Germersheim.

| Parameter | Measure | Remarks |
|---|---|---|
| Location | U.S. Depot, Germersheim | |
| Footprint | 15 m x 65 m | |
| Roof Characteristic | Ridge Roof | |
| Inclination | 170 | |
| Orientation | 1800 | |
| Area of PV-System | 390 m² | |
| No. of Modules | 600 | |
| Output | 48 kWp | |
| Roof Load/m² | 17.5 kg | |
| Estimated yearly results | | |
| Specific Annual Yield | 970 kW/kWp | Approximately 10% higher than shown in Figure 8 |

* http://www.pv-ertraege.de/cgi-bin/pvdaten/src/region_uebersichten.pl/kl

| Parameter | Measure | Remarks |
|---|---|---|
| Grid Feed-in/yr | 46,503 kWh | First year/Degradation: 5% in 20 yrs |
| Total Revenue (20 yr period) | €416,861 | Installation End 2008 |
| Total Revenue (20.5 yr period) | €406,153 | Installation Mid 2009 |
| Investment Cost* | €218,208 | Total Investment costs including installation |
| Investment Cost/kWp* | €4,546 | |
| Break even time (without capital cost) | 10/11 yrs | Installation 2008/2009 |
| Liquidity cumulated (with capital cost) | €95,739/€85,031 | Installation 2008/2009 |
| Real rate of return | 44%/39% | Installation 2008/2009 |
| $CO_2$ Reduction cumulative | 299 t/307 t | Installation 2008/2009 |
| * Orientation Price of Würth Solar – Reduction after purchase negotiations = 15% lower investment | | |

**Economic efficiency calculation 2008/2009**

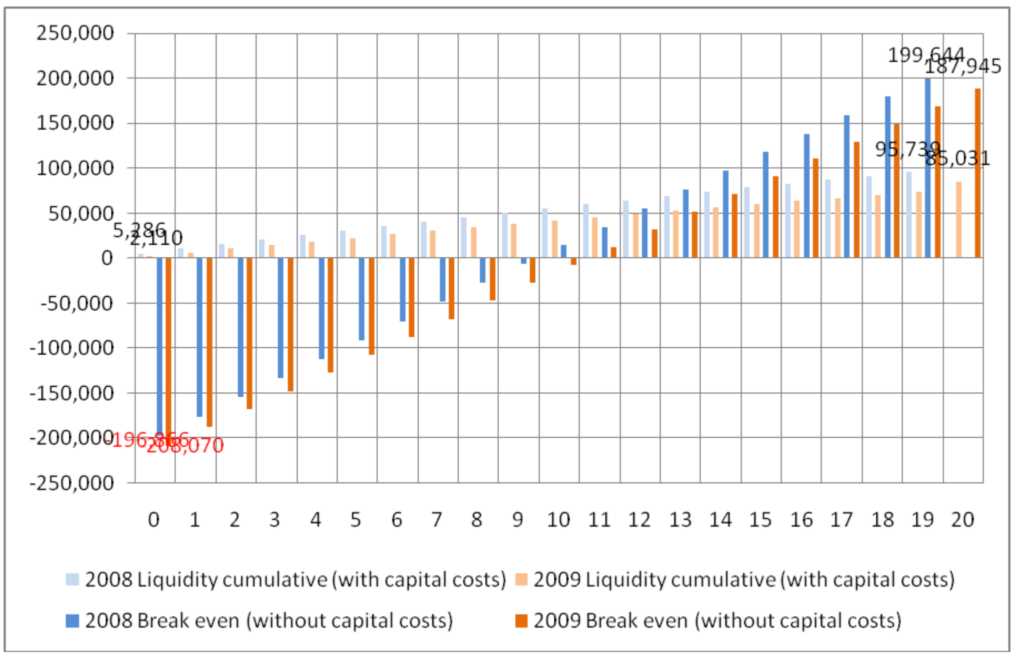


Figure 25. Economic efficiency calculation – installation through the end of 2008.

For both cases, the economic efficiency calculations (Figure 25) assume an interest rate of 4 percent over the 20-yr period. The break-even calculations over the 20-yr period do not include capital costs, therefore:

- Break even 2008: 10 yrs
- Break even 2009: 11 yrs.

In case of a full financing model, the accumulated liquidity including the capital costs are:

- Accumulated Liquidity 2008: €95,739
- Accumulated Liquidity 2009: €85,031.

### Conclusion

In Germany, it is recommended that PV-System installation occur in 2008. An installation of PV-Systems in 2009 or later will lower the profitability because of the declining funding values. In Italy or Belgium other regulations are in place.

### Environmental aspects

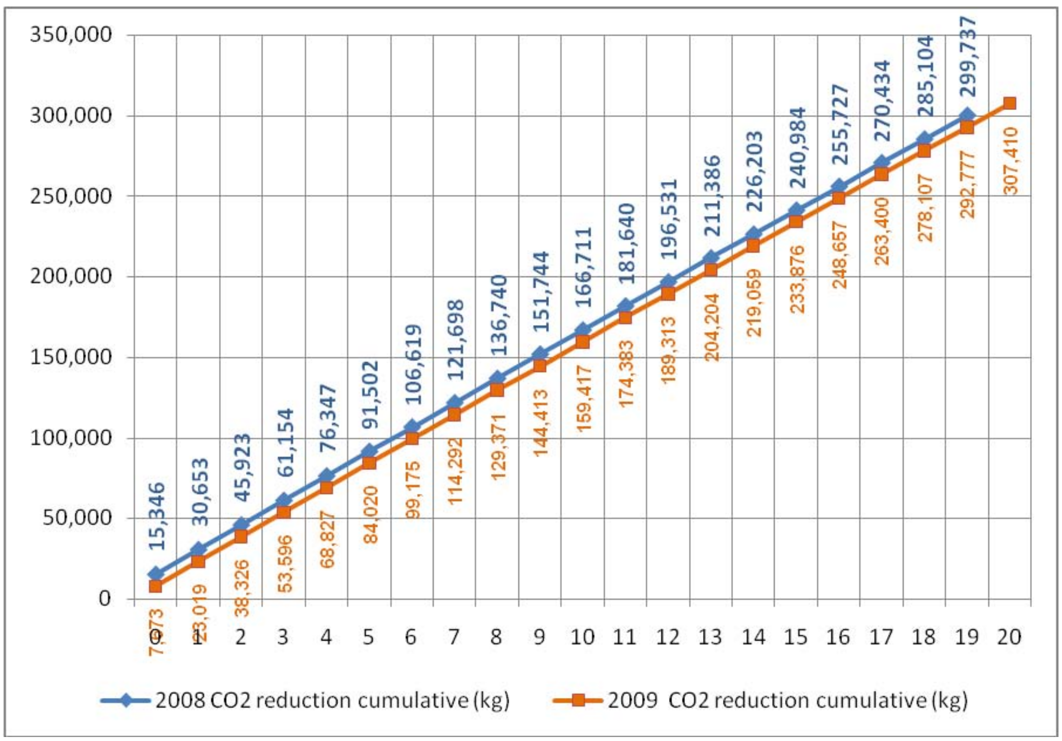


Figure 26. Cumulative $CO_2$ reduction.

The Example PV-System of Bldg 7889 in Germersheim will reduce the greenhouse gas emission by approximately 300 tons over the 20-yr period (Figure 26).

# 4 Energy Conservation Measures (ECMs)

## Campbell Barracks – Heidelberg

### ECM CEP#1CA Analysis of the secondary heating system pumps, adjustment of the size and operation mode

*Existing Conditions*

Currently the secondary heating system pumps (Wilo-P/RP, analog, Figure 27) are running 24 hrs/day under full load. The pumps, which must be removed because they are worn out, are to be replaced by new digital (Grundfos Magna or Alpha) pumps.

The Magna circulator pump is built around a permanent-magnet motor and an integrated frequency converter. The differential pressure across the pump is automatically adjusted to match the flow. When the flow drops, so does the pressure required. This results in a correspondingly reduced load on the motor – and reduced energy consumption.


Figure 27. Wilo-P analog pump.

The Alpha circulator pump is similarly to the Magna pump, but is equipped with the autoadapt control system. The pump searches automatically for the lowest delivery height for the fulfillment of the installation requirements (optimum working point).

The pumps of the main station, which have already been exchanged, should result in savings of about 50 percent.

The main station is supplied by hot water with a supply temperature of about 115 °C at most. The return temperature is about 55 °C. Current measured values read from the master display (29 September 2008) were: supply temperature 113 °C and return temperature 54 °C in front of the inflow into the main station, supply temperature 70 °C and return temperature 55 °C on the net side, output of the main station 622 kW at an angle of aperture of 33 percent and differential pressure of 1.16 bar. The critical customers are Bldgs #38 and #40.

The installed capacity at the main station is 5 MW (two heat exchangers each with 2.5 MW). The variable operation mode of the supply temperature is preset in the control system by the gradient of the driving cycle.

Programming the public holidays into the control system would yield savings of about $ 4,000 – $ 5,000 per heating period.

*Solution*

The substitution of the Wilo-P/RP analog pumps by Grundfos Magna/Alpha pumps occurs step by step. As soon as an old pump breaks down, a new digital Grundfos pump will be installed. The Grundfos Magna/Alpha pumps are energy-saving pumps of the energy efficiency grade A; they automatically adapt their working point to the demand.

*Savings*

A simple comparison of the current consumption of the Wilo-P65 pump and new Grundfos pumps follows:

Wilo-P65: 15.5 kWh/day x 270 days = 4,185 kWh

Grundfos: 5.5 kWh/day x 270 days = 1,485 kWh

Savings = 2,700 kWh

That results in savings of about €260 per pump when the costs for electricity are 9.5 ct/kWh:

2,700 kWh x 8.9 ct/kWh = €241 per pump

*Investment cost*

The retrofitting for every substation with a new VFD pump (Grundfos Magna/Alpha) costs about €2,500 per station.

*Payback*

The resulting simple payback period for the exchange of one pump:

€2,500/€241 = 10.4 years.

#### ECM CEP#2CA Additional bio-diesel fired cogeneration motor

*Existing Conditions*

The gas fired co-generator was shut down after 18 years of non-stop operation. It will need a general overhaul if it is to be used further.

There were investigations for a new vegetable oil co-generator, but the costs for the vegetable oil (70 ct/L) are too high. In comparison the reference price for district heating amounts to €38.40/MWh. For this reason, the Campbell Barracks obtain energy for their district heating and cooling system via a DN 800 district heating pipe directly from the MVV super power plant in Mannheim.

The existing gas turbine (47 $kW_{el}$, 90 $kW_{th}$) runs and is responsible for a frictionless operation.

*Solution*

A new Bio-Diesel fired co-generator could be installed to cover the basic heating and cooling load. Therefore, economic efficiency that takes the bio-diesel co-generator into consideration must be calculated to compare the current heat delivery costs €38.40/MWh with the resulting heat costs.

*Savings*

The total heat demand in the financial year 2008 (Figure 28) amounts 8,281,000 kWh for heating and 3,503,000 kWh for cooling, total 11,784,000 kWh (see Figure 28).

The co-generator shall cover 25 percent of the basic load. Thus a co-generator with the following specifications will be chosen:

- number of modules 1
- electric power 300 kW
- thermal output 400 kW
- averaged operating time 7,500 h/yr
- produced electric energy 2,250 MWh/yr
- produced heat energy 3,000 MWh/yr
- electrical efficiency 35%
- thermal efficiency 52%
- total efficiency 87%
- fuel provided Bio-Diesel 6,034 MWh/yr.

Consequently, the heat delivery from the MVV will be reduced to 8,784 MWh/yr using a co-generator for the basic load.

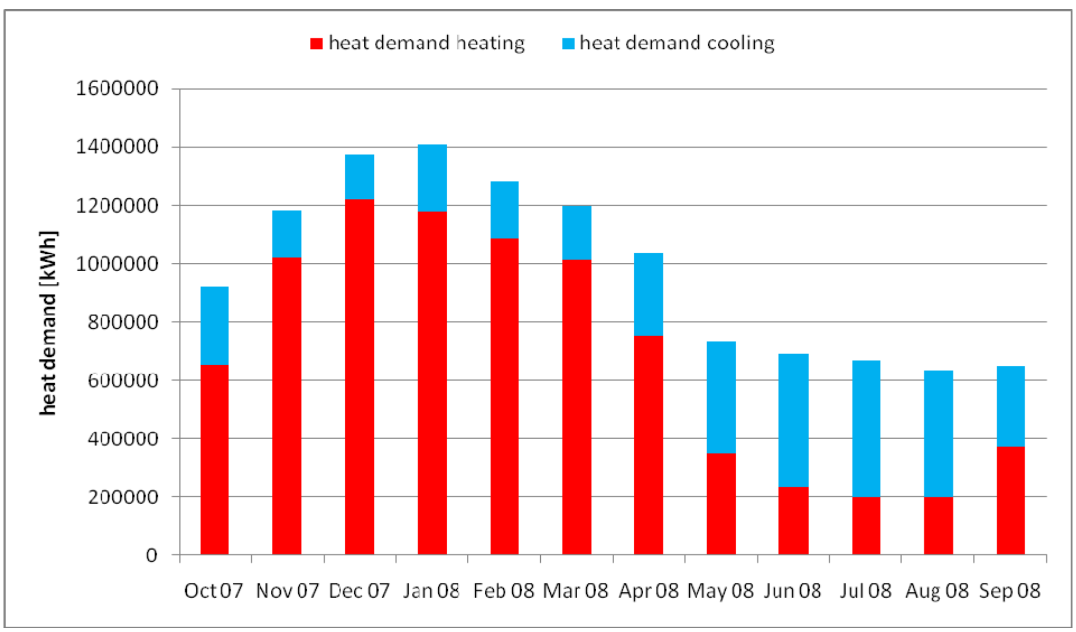


Figure 28. Heat demand for heating and cooling in the financial year 2008.

The costs for the Bio-Diesel fired co-generator are composed of the investment cost, the costs of maintenance, other costs like administration costs, and the costs for Bio-Diesel:

- Investment cost:
  - investment cost cogeneration motor €240,000
  - installation engineering €150,000
  - permit, planning, other €39,000
  - <u>extraction of electricity €20,000</u>
  - **total €449,000**
- Costs of maintenance include: 1.26 ct/kWh$_{el}$:
  - maintenance and repair work
  - spare parts
  - operating materials (excepting fuel)
  - general overhaul in 10 years
- Other costs:
  - assurance, administration 1.50% of invest.
  - lube oil consumption 0.16 kg/h
  - lube oil costs €2.20/kg.

The recovery period for the co-generator should be 15 years at an interest rate of 6 percent p.a. That results in an amount of annuity of 10.3 percent.

The costs for the Bio-Diesel co-generator per year are consequently:

- total investment cost €46,230/a
- maintenance €28,362/a
- assurance, administration €6,735/a
- lube oil supply €2,640/a
- costs for Bio-Diesel (to be calculated).

The heat delivery costs for the remaining heat demand in the amount of 337,300,- €/a are still missing and must be added to the annual costs.

The revenues caused by the combined generation of heat and power are:

- power generation €123,750/a (electricity tariff 55 €/MWh)
- <u>aid CHP-law €47,250/a</u> (aid money 21 €/MWh)
- **total revenues €171,000/a**.

Only with costs for Bio-Diesel less than €33.5/MWh a profit will be achieved.

*Investment*

The installation costs for the Bio-Diesel fired co-generator amount to €449,000 without maintenance (and other) annual expenses.

**HVAC #1CA – Repair leaking hot water valve — Bldg 18**

*Existing conditions/problems*

The heat control valve in the main air handling unit (AHU) is leaking. The hot water (HW) pumps were not switched off so the heating coil was supplied with 110 °F (44 °C) hot water. Thus, the Outside Air (OA) was heated before entering the cooling coil, making the chiller run more than needed.

*Solution*

Repair or replace the leaking heat control valve. Ensure sure that the HW pump is switched OFF during the cooling season.

*Savings*

Assume that the mass flow through the heating coil is 2.5 kg/s and the temperature drop of the circulating hot water is 20 °C. The heat loss is:

2.5 kg/s * 4.18 kJ/kg. °C * 20 °C = 209 kW

The hours of operation for the AHU is assumed to match the building occupancy plus 1 hr before and after the building is opened and closed, or 113 hrs/wk. The weekly energy losses related to heat then is:

209 kW * 113 hrs = 23,600 kWh

If nothing is done to solve the problem, this situation will recur throughout the cooling season. Cooling is needed from May to September, or 20 wks/yr, such that total heat losses are calculated as:

20wks * 23,600 kWh/wk = 472,000 kWh at a cost of €17,400.

Additionally, the chiller must run excessively to remove these 472 MWh of heat in addition to cooling the OA. With an estimated chiller coefficient of performance (COP) of 3.0, this means that 472/3.0 = 157 MWh of electricity (worth another €14,000) will be used unnecessarily. Total savings are:

Total savings 17,400 + 14,000 = €31,400/summer

*Investment*

The required investment should not exceed €2,000.

*Payback*

The resulting payback will occur within 0.1 yr.

### HVAC #2CA – Adjust HVAC unit outdoor air using $CO_2$ sensors — Bldg 22

*Existing conditions/problems*

The AHU supplying the Communication center in Bldg 22 at Campbell Barracks runs at approximately 30–40 percent OA. The building occupancy is such that the AHU runs 24/7. The building is not heavily manned (definitely not 24/7). Thus, the use of outdoor air (OA) could be controlled by occupancy of the building. The building is served by a local chiller that, during the site visit, ran at 55 percent loaded. It has two compressors rated at 76 kW each. The ΔT at that point was very low; supply temperature 4.6 °C and return temperature 7.2 °C.

*Solution*

Install $CO_2$ sensors that can provide information on the number of people that occupy the spaces, and thus control the amount of OA needed to make the air comfortable.

*Savings*

Based on its physical size, assume that the AHU supplies 30,000 $m^3/h$ or 8.3 $m^3/s$ into the building and that 30 percent or 2.5 $m^3/s$ is OA. $CO_2$ sensors will be able to reduce the amount of OA to approximately 10 percent or 0.8 $m^3/s$. The AHU runs 24/7. Mannheim has the following heating and cooling degree days:

- HDD = 5,441 °F = 3,022 °C
- CDD = 526 °F = 292 °C.

Heat savings are calculated as:

Heat savings (2.5 – 0.8 $m^3/s$) * 1.0 $kg/m^3$ * 1.2 kJ/kg °C
* 3.022 heating degree-days * 24 hrs = 148,000 kWh of heating

The value of heat savings at €36.8/MWh thermal = €5,450 annually:

Cooling savings (2.5 – 0.8 $m^3/s$) * 1.0 $kg/m^3$ * 1.2 kJ/kg. °C
* 292 cooling degree-days * 24 hrs/3.0 (COP) = 4,800 kWh of electric energy

The value of the cooling savings at €89.3/MWh = €430 annually:

Total savings = €5,900

*Investment*

The required investment is estimated to be in the range of €4,000 with two sensors (use average readings) and re-programming controls.

*Payback*

The resulting payback will occur within 0.7 yrs.

**HVAC #3CA – Modify building controls to allow HVAC unit to use less than 100 percent OA — Bldg 18**

*Existing conditions/problems*

The main Air Handling Unit. AHU, which supplies the gym Bldg 18 at Campbell Barracks, operates at 100 percent OA. This is highly inefficient. Figure 29 shows the OA damper 100 percent open.

*Other observations regarding Bldg 18*

Some windows were open, with the cooling coil operational cooling the space down to 68 °F (20 °C). This means that energy is wasted. The entrance door was blocked in a totally open position (Figure 30) allowing warm air to infiltrate the building and cold air to leave.

Figure 29. Bldg 18 OA damper.

Figure 30. Bldg 18 front door propped open.

*Solution*

Change the controls so that this AHU runs at a minimum of 10 percent OA whenever there is a need for heating or cooling. The infiltration into the building is sufficient, together with 10 percent OA, to provide the fresh air that is needed for the occupants. Consider installing switches on the windows and entrance doors that turns off the cooling (or heating in winter) when the windows and/or doors are open.

*Savings*

The AHU is supplying 51,200 $m^3/h$ = 14.2 $m^3/s$. The hours of building occupancy are Mon–Fri 0500–2200 hrs, and Sat–Sun 1000–1700 hrs. Hours of operation for the AHU are assumed to be Mon–Fri 0400– 2300 hrs, and Sat–Sun 0900–1800 hrs. The exact hours the AHU runs were unknown; it could very well be running continuously. Savings gained by reducing the OA from 14.2 to 1.4 $m^3/s$ during an average of 16 hrs/day may be calculated as:

Savings heating = (14.2 – 1.4 $m^3/s$) * 1.0 $kg/m^3$ * 1.2 kJ/kg °C

* 3.022 heating degree-days * 16 hrs = 743,000 kWh of heating

Value of the heat savings with €36.8/MWh thermal = €27,300 annually

Cooling savings (14.2 – 1.4 $m^3/s$) * 1.0 $kg/m^3$ * 1.2 kJ/kg °C
* 292 cooling degree-days * 16 hrs/3.0 (COP) = 23,900 kWh of electric energy
Value of the cooling savings with €89.3/MWh thermal = €2,100 annually
Total savings = €29,500/yr

*Investment*

Re-programming the operation of the AHU to allow 10 percent OA during heating and cooling seasons and to modulate for free cooling during spring and autumn will not cost more than €1,000.

*Payback*

The resulting payback will occur within 0.1 yr.

*Investment*

Re-programming controls should require an investment of no more than €100/mechanical room. Pumps may be manually switched off as part of the DPW personnel's normal work.

*Payback*

The resulting payback will occur within 0.3 yr.

### HVAC #4CA – Install absorption chiller driven by solar collectors to replace electric chiller — Bldg 3983

*Existing conditions/problems*

This ECM is actually at the DPW, Bldg 3983 in Heidelberg (behind DPW headquarters) and it is an office building with a flat roof, cooled by a Technibel chiller with 101 kW cooling capacity and 52.6 kW maximum electricity demand. The chiller supplies cold water at 10 °C to fan coil units inside the building. There are plans to install meters for this chiller to keep track of the energy use. The roof should be a good platform for solar panels although the construction needs to be double-checked to verify that the unit can carry the extra load.

*Solution*

Install solar panels on the roof of the building. The solar panels shall be designed to supply 90 °C water to an absorption chiller with 70 °C water return from the chiller. Install an absorption chiller. Proposed is a York WFC-SC 20 with 70 kW cooling capacity that supplies 7 °C water and that has a design return temperature of 12.5 °C. The only electricity used is for a pump at 260W.

The COP of the absorption chiller is around 0.70 so the solar collectors must provide 100 kW of heat to get 70 kW of cooling capacity from the chiller. This provides the design data for the solar collectors indicating the need for 155 $m^2$ of solar collectors with radiation of 1,000 $W/m^2$ and 66.8 percent efficiency of the collectors.

*Savings*

It is estimated that the present chiller runs at 60 percent capacity on average during the cooling season, thus using the following amount of electric energy:

52 kW * 0.60 * 120 days * 24 hrs = 90,000 kWh/yr.

Installing the absorption chiller driven by heat from the sun would only require:

260 W * 120 days * 24 hrs = 750 kWh/yr.

Net electricity savings, then, are 89,000 kWh/yr, worth €8,000 annually.

*Investment*

The price for the WFC SC 20 absorption chiller is approximately €45,000 including controls, but excluding the solar panels. Installation cost is calculated to be €6,000. A cooling tower or a dry cooler must also be installed in addition to the absorption chiller. The estimated cost for the dry cooler is €9,000. The costs for the solar panels installed and connected is calculated to be €180,000. This results in a total investment of €240,000.

*Payback*

At present electricity prices, the resulting payback will occur within 30 yrs.

## LI #1CA – Use occupancy sensors to turn off lights

*Existing conditions*

At Campbell Barracks, a number of buildings are used throughout the day with high and low periods of occupancy (Figure 31). Visits of these buildings found overhead lights on with a minimum of personnel present. Many of the lights could be shut off in unoccupied spaces to save electricity.

*Solution*

In spaces where use varies depending on the time of day and/or current activities, the lighting system can be best controlled by occupancy sensors. Occupancy sensors can be installed that automatically switch lights on when human movement is sensed. The lighting level will be maintained until a set period of time has elapsed with no human movement observed. A period of 5 to 10 minutes would be adequate to ensure the space is truly unoccupied.

Such lighting controls should be placed in all buildings at Campbell Barracks that have varied use patterns. These spaces should also have fluorescent lighting since the time for the bulb to light is almost instantaneous.

Figure 31. Empty space with lights on.

Lighting systems using sodium vapor mercury vapor or metal halide lights take several minutes for measurable light to be produced after energizing the bulb and thus are not conducive to occupancy sensor control. If the lighting in these spaces is not better controlled this energy waste will continue.

*Savings*

Table 10 lists summary data of the savings potential based on the spaces visited. The total estimated energy cost savings is €114/yr.

*Example calculation – Bldg 152 locker room*

Electrical savings = six fixtures * 0.064kW * 80.5 hr/wk * 52 wk/yr = 643 kWh/yr

Electrical cost savings = 643 kWh/yr * €0.0893/Kwh = €57/yr

*Investment*

The cost to install an infrared wall mounted occupancy sensor is approximately €200 each for a simple replacement of the light switch. Where a remote sensor may be needed, a higher cost of €300 is provided. The total investment of the visited spaces identified in this ECM is €1,100.

*Payback*

The payback for lighting controls in the subject building is 9.7 yrs. This is somewhat long due to many spaces evaluated had few lights. Spaces with varied schedules having more than four lights would have a better payback. It is recommended that occupancy sensors be placed in all such spaces that have fluorescent lighting.

Table 10. Savings potential of using occupancy sensors to turn off lights.

| Bldg | Space | Lights (W) | No. lights | Hrs/wk | % Off | Hrs off /wk | kW Saved /yr | Cost Saved | Sensor Cost | Payback Period |
|---|---|---|---|---|---|---|---|---|---|---|
| 152 | Locker Room | 64 | 6 | 80.5 | 40% | 32.2 | 643 | 57 | 300 | 5.2 |
| | Sauna | 64 | 2 | 80.5 | 40% | 32.2 | 214 | 19 | 200 | 10.4 |
| | Showers | 64 | 1 | 80.5 | 30% | 24.15 | 80 | 7 | 200 | 27.9 |
| | Restroom | 64 | 2 | 80.5 | 25% | 20.125 | 134 | 12 | 200 | 16.7 |
| | Toilet Area | 64 | 3 | 80.5 | 25% | 20.125 | 201 | 18 | 200 | 11.1 |
| | Total | | | | | | 1272 | 113 | 1100 | |

### LI #2CA – Change bulbs in exit lights

*Existing conditions*

The exit signs in many of the buildings (Figure 32) are equipped with ordinary fluorescent lights that use approximately 11W of energy. These lamps have an estimated life 7,500 hrs. These lamps were found in many of the buildings visited (Table 11).

*Solution*

The fluorescent lighted exit signs can be replaced with ones that use a more efficient light emitting diode (LED) lamp that also has a longer life. A LED lighted exit sign that uses less than 1W should be used to replace all the fluorescent lighted exit signs in the buildings.

*Savings*

LED exit lights provide a savings of 10W. An exit sign is illuminated continuously, 8760 hrs/yr. The LED type lamp has a life of over 10 yrs where the fluorescent lamp must be replaced approximately every 10 months. The economics of replacing the fluorescent lamps may be expressed as:

The savings for a single fixture = 10W * 8760 hrs/yr = 87.6 kWh/yr

The electrical cost savings = 87.6 kWh/yr * €0.0893/kWh = €7.82/yr

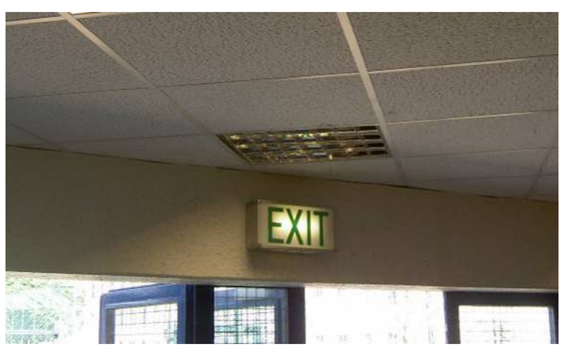


Figure 32. Fluorescent light exit sign.

Table 11. Economics of replacing fluorescent lamps.

| Bldg | Lights (W) Saved | No. lights | hrs/wk | kWh Saved /yr | Electrical Cost Savings | New Lamp Replacement Material + Labor Cost | Lamp Life. Yrs | Annual cost Replacement | Annual O&M Savings | LED Cost | Payback Period |
|---|---|---|---|---|---|---|---|---|---|---|---|
| HQ Bldg | 10 | 6 | 168 | 524 | €47 | €15 | 0.86 | €105 | €137 | €600 | 4.4 |
| 152 | 10 | 5 | 168 | 437 | €39 | €15 | 0.86 | €87 | €114 | €500 | 4.4 |

There is also a savings due to the longer lamp life. A fluorescent replacement lamp will cost approximately €5.00 and the labor of this replacement is estimated to be ¼ hr:

Fluorescent lamp replacement cost = (€5 + 0.25 * €40)
 * 8760 hrs/yr/7500 hrs bulb life = €17.52/yr
LED lamp replacement cost = (€50 + 0.25 * €40)
 * 8760 hrs/yr/100.000 hrs bulb life = €5.26/yr

The replacement bulb cost savings of the LED bulb is approximately €12.00/yr

The total annual saving per exit sign of the LED bulb is approximately €20.00/yr

There are an estimated six exit signs in the headquarters (HQ) building at the Mark Twain Barracks and five in the nearby Gym (Bldg 152). The total savings for replacing these exit lamps is €220/yr. There are many more exit signs at this site as well as Campbell Barracks. Assuming an exit sign yields a total savings of €200, the total savings would be €4,000/yr. It is therefore recommended that all exits be upgraded.

*Investment*

LED replacement kits are available at a cost of about €50, which includes the necessary hardware to convert a fluorescent exit sign to LED. This conversion requires approximately 1 hr labor. At €40/hr for labor, the cost to switch a fluorescent exit sign to a LED type is €90. Using the 200 exit sign number from above the total cost of this project is €18,000.

*Payback*

The payback for LED exit lights is 4.5 yrs. It is recommended that all fluorescent exit lights be replaced with a LED type.

### DIN #1CA – Use kitchen hood control — Bldg 112

*Existing condition*

Figure 33. Kitchen hood that is good candidate for variable air flow.

Kitchen hoods located in the Dining Facility at Mark Twain Barracks typically operate through the working hours of the kitchen. These hoods continue to exhaust air even though when the stoves are unoccupied (Figure 33). The hoods operate unnecessarily, wasting energy. Table 12 lists calculated savings from using four different sizes of variable air flow kitchen hoods. It is estimated that the dining facilities operate 13 hrs/day every day of the week, and that cooking occurs under the hoods for approx. 7 hrs/day (54 percent of the time).

Table 12. Calculated savings from using variable air flow kitchen hoods.

| Hood Size | Exhaust Air. CFM | Estimated Motor Hp | Operating Hrs./wk | Reduced Air Flow | Motor Hp Savings.% | Low Flow% of Time | kWh Saving/Yr |
|---|---|---|---|---|---|---|---|
| 10 X 3 | 5,000 | 5 | 91 | 2,500 | 80% | 46% | 6,495 |
| 16 X 2 | 4,800 | 5 | 91 | 2,400 | 80% | 46% | 6,495 |
| 20 X 4 | 6,000 | 7.5 | 91 | 3,000 | 80% | 46% | 9,743 |
| 8 X 4 | 2,400 | 3 | 91 | 1,200 | 80% | 46% | 3,897 |
| *Totals* | *18,200* | | | *9,100* | | | *26,630* |

*Solution*

Sensors can be placed on the exhaust hood system that will vary the air flow from full flow down to half flow. An optic sensor in the hood (Figure 34) will monitor the presence of smoke and cooking vapors. A temperature sensor placed in the duct attached to the hood will note an increase in temperature. The start of cooking activities under the hood will provide a positive indication by either of these sensors and the exhaust air flow will be increased to full flow.

*Savings*

Figure 34. Exhaust fan controls.

The following analysis uses the first hood to exhibit the savings calculations. The kitchen hood has cooking operations for an estimated 7 hrs/day. For 6 hrs/day, its air flow could be reduced from 5,000 cubic feet per minute (CFM) to a flow of 2,500 CFM for each hood, reducing the horsepower use equal to the cube of 2,500/5,000 or about 20 percent of the 5 hp when motor losses are included. Savings are 80 percent (including motor losses) of the motor electrical use over the 6 hrs/day or 42 hrs/wk. Heating energy is also saved from reduced makeup air requirements.

Fan motor power reduction = 5 hp * 80% * 0.746 kW/hp * 91 hrs/wk
* 52 wk/yr * 46%= 6,495 kWh/yr.

The total fan motor electrical savings for the four hoods is 26,630 kWh/yr.

Electrical cost savings = 26,630 kWh/yr * €0.0893/kWh= €2,390/yr

Heating savings = 1.08 * 18,200 CFM * 50% * 5441 degree days * 24 hr/day
* 6 hrs/24hrs/0.7 boiler efficiency = 458 million Btu/yr or 134 mWhth/yr

Heating cost savings = 134 mWhth/yr * €36.8/mWhth/yr = €4,930/yr

The total estimated cost savings is €7,320/yr.

*Investment*

The estimated cost to provide temperature and smoke detectors and the controls to adjust fan speed for the exhaust and supply air system is approximately €25,600. The cost to have variable speed drives for the motors listed in Table 12 is €16,600 for a total cost of €42,200.

*Payback*

The resulting payback period is 5.8 yrs.

## Summary

Table 13 summarizes the ECMs for Campbell Barracks.

Table 13. Summary of Campbell Barracks ECMs.

| ECM # | ECM Description | Electrical Savings | | Thermal | | Maintenance (€/yr) | Total Savings: Electrical Use, Elec Demand, Thermal, and Maint (€/Yr) | Investment (€) | Simple Payback (yrs) |
|---|---|---|---|---|---|---|---|---|---|
| | | KWh/yr | €/yr | MMBtu/yr | €/Yr | | | | |
| CEP #1CA | Analysis of the Secondary Heating System Pumps, Adjustment of the Size and Operation Mode | 2,700 | €241 | 0 | €0 | €0 | €241 | €2,500 | 10.4 |
| CEP #2CA | Additional Bio-Diesel Fired Cogeneration Motor | 2,250,000 | €0 | 10239 | €0 | €28,362 | €171,000 | €449,000 | 15* |
| CEP #3CA | Optimization of the Central Cooling System | 0 | €0 | 314 | €26,900 | €0 | €26,900 | €343,000 | 12.8 |
| DIN #1CA | Use Kitchen Hood Control, Bldg 112 | 26,630 | €2,378 | 458 | €4,938 | €0 | €7,316 | €42,200 | 5.8 |
| HVAC #1CA | Repair Leaking Hot Water Valve, Bldg 18 | 157,000 | €14,020 | 1611 | €17,370 | €0 | €31,390 | €2,000 | 0.1 |
| HVAC #2CA | Adjust HVAC Unit Outdoor Air Using $CO_2$ Sensors, Bldg 22 | 4,800 | €429 | 505 | €5,446 | €0 | €5,875 | €4,000 | 0.7 |
| HVAC #3CA | Modify Building Controls To Allow HVAC Unit Not Use 100% OA, Bldg 18 | 23,900 | €2,134 | 2536 | €27,342 | €0 | €29,477 | €1,000 | 0.0 |
| HVAC #4CA | Install Absorption Chiller Driven by Solar Collectors To Replace Electric Chiller, Bldg 3983 | 89,000 | €7,948 | 0 | €0 | €0 | €7,948 | €240,000 | 30.2 |
| LI #1CA | Use Occupancy Sensors To Turn off Lights | 1,272 | €114 | 0 | €0 | €0 | €114 | €1,100 | 9.7 |
| LI #2CA | Change Bulbs in Exit Lights | 17,520 | €1,565 | 0 | €0 | €2,400 | €3,965 | €18,000 | 4.5 |
| *Totals* | | *2,572,822* | *28,828* | *15,663* | *81,997* | *30,762* | *284,225* | *1,102,800* | *4* |

## Coleman Barracks – Manheim

### BE #1CO – Install panels in areas having single pane windows — Bldg 25

*Existing conditions*

Some of the second floor windows in Bldg 25 have single pane glass panels that allow sunlight to enter the building. Unfortunately the single pane glass is a very poor insulator for heat transfer. This building is approximately 30 ft high with the single pane glass area of 1,500 sq ft.

This building is heated and the single pane glass (Figure 35) causes excessive heat loss in the winter due to its poor insulating value. The construction of the windows is fairly air tight and allows little infiltration of outdoor air.

*Solution*

Remove existing windows and install transparent plastic panels in these window areas. The new plastic panels (Figure 36) will allow most of the natural light to enter the building. The panels will provide a resistance to heat transfer due to layers of isolated air spaces in the panels. The proposed panel has three such layers providing an insulation value of approximately 0.5 Btu/sq ft/°F.

Figure 35. Single pane windows in second story of Bldg 12.

Figure 36. New plastic panels – cross section.

*Savings*

The placement of the transparent panels where the existing single pane windows are located will reduce the heat loss through the windows by 57 percent:

Q = (1.17 – 0.5) Btu/sq ft/°F * 1.500 sq ft * (5133 degree days * 24 hrs/day = 124 million Btu/yr or 36.3 $mWh_{th}$/yr

Cost Savings = 36.3 $mWh_{th}$ * €36.8/$mWh_{th}$ = €1.336/yr

*Investment*

The estimated cost to prepare the inside of the windows and install the new transparent panels is €10/sq ft plus an additional cost €5,000 for removal of the existing windows equaling a total installation cost of €19,800:

1500 sq ft * €10/sq ft. = €15,000

*Payback*

The resulting payback period for the window enhancement is 14.8 yrs.

**BE #2CO – Reduce door size — Bldg 49**

*Existing conditions*

In Bldg 49, there are two very large doors (approximately 35x35-ft high) that open into storage and vehicle maintenance areas (Figure 37). The objects that must enter the building are much smaller than the size of these doors. The size of these doors can be reduced without affecting the function of the building. When these doors are opened, large quantities of outdoor air enter the buildings. This increases the heating load in the winter. The doors also have a poor insulation value allowing excessive heating energy to escape to the outdoors during the heating season. The present “U” value is estimated to be 0.60/sq ft/°F. Finally, smaller doors will have less crack area that will reduce the infiltration of outdoor air. It is estimated there is an ¼-in. crack around the door for a crack area of 2.9 sq ft.

*Solution*

These door openings can be fitted with smaller doors (20-ft wide x 25-ft high) with the surrounding wall space filled with an insulated removable panels to provide a greater resistance to heat loss. The proposed panels would be fiber glass or metal covered foam sections that will occupy the 10-ft high space above the new door and the 15 ft space on the side of the door. These fill panels would be screwed together providing a smooth surface. Provisions will be made to allow easy disassembly if a larger opening is needed. The estimated new insulating value of these panels is 0.09 Btu/sq ft/°F. If these doors are not replaced with smaller ones excessive heating energy for this building will continue.

Figure 37. Large door in Bldg 49.

*Savings*

The difference in insulating value between the door section and the proposed insulating panel will provide an energy saving of 26.7 $mWh_{th}$/yr. These big doors cause large amounts of OA to enter the building when they open. It is estimated the doors open an average of four times a day for 5 minutes each time. The difference of the door area is 1,225 sq ft minus 700 sq ft or 525 sq ft for each door. OA can also enter through the crack area around the existing doors (which is estimated to be 2.9 sq ft); with the new doors, this crack will be reduced to 1.8 sq ft using the same ¼-in. wide crack. Thus the larger doors have a crack area 2.2 sq ft bigger. Using an average incoming velocity of 100 ft/minute (FPM) this will equal an infiltration of 220 CFM/. The installation of the door panels will also reduce the amount of OA that enters the building providing an additional savings of 58.4 MWHth for a cost savings of €2,150/yr. Thus, the savings from reduced conduction and infiltration are:

$Q_{conduction}$ = (0.60 – 0.09) Btu/sq ft/°F * 1.450 sq ft * 5133 degree days * 24 hr/day
= 91 million Btu/yr or 26.7 $mWh_{th}$/yr

$Q_{infiltration}$ = 1.08 * 100 CFM * 20min/60 min/hr * 525 sq ft * two doors
* (65 – 40) °F * 180 days/yr/3413000 Btu/MWH = 49.8 $mWh_{th}$/yr

$Q_{infiltration}$ = 1.08 * 220 CFM * 5133 degree days * 24 hr/day
= 29 million Btu/yr or 8.6 $mWh_{th}$/yr

The total energy cost savings is therefore €3,130/yr.

Cost Savings = (26.7 + 49.8 + 8.6) $mWh_{th}$ * €36.8/MWH = €3,130/yr

*Investment*

The total door area to be filled is 1,450 sq ft. Using a cost of €10/sq ft the total estimated installed cost is €14,500. The cost of the two new doors would be €15,000 each. The total cost for reducing the door size would be €44,500.

*Payback*

The resulting in a payback of the installation of these door panels of 14.2 yrs.

### CEP #4CO – Substation optimization

*Existing Conditions*

The following substations, which are representative of the rest of Coleman Barracks, were visited:

- Bldg 53 – barrack
- Bldg 45 – cafeteria
- Bldg 49 – storage/post
- Bldg 57 – motor pool
- Bldg 25 – gym
- Bldg 4a – hangar
- Main station of the energy supplier MVV, near the church.

The stations correspond to the state of the technology and are in a good condition.

*Bldg 53 – Barrack*

The station supplies the building with heat for:

- a radiator
- domestic hot water.

The existing control on the secondary system controls the two heating circuits according to the outdoor temperature and the demand. The mentioned direct transfer station has essential fittings that are important for a safe supply, like:

- pressure reduction
- volume/differential pressure regulator
- shut-off valves/dirt arrester.

*Notes for the substation*

- The substation has no isolation.
- The isolation for the boiler is not fitted correctly that causes heat loss (Figure 38).
- There is no heat meter. The heat consumption is measured at the main station for all consumers. Consequently there is no correlation, control and (if necessary) accounting of consumption possible.


Figure 38. Substation of Bldg 53 (barrack) with no isolation.

*Bldg 45 – Cafeteria*

The station supplies the building with heat for:

- a radiator
- a ventilation system
- domestic hot water.

The existing control on the secondary system controls the two heating circuits according to the outdoor temperature and the demand. The mentioned direct transfer station has essential fittings that are important for a safe supply, like:

- pressure reduction
- volume/differential pressure regulator
- shut-off valves/dirt arrester.

*Notes for the Substation*

The isolation for the domestic water boiler is damaged and must be replaced to avoid more heat loss (Figure 39).


Figure 39. Domestic water boiler with damaged isolation in Bldg 45 (cafeteria).

There is no heat meter and so no accommodation for the buildings. A control or accounting of consumption is not possible.

*Bldg 49 – Storage/Post*

The station supplies the building with heat for:

- a radiator
- domestic hot water.

The existing control on the secondary system controls the two heating circuits according to the outdoor temperature and the demand. The mentioned direct transfer station has essential fittings that are important for a safe supply, like:

- pressure reduction
- volume/differential pressure regulator
- shut-off valves/dirt arrester

*Notes for the Substation*

At an outdoor temperature of approximately +25 °C (77 °F), a heating pump was in operation although there was no heat demand (Figure 40).


Figure 40. Heating pumps in Bldg 49 (storage).

That means the control does not stop the pump at a high outdoor temperature. An automatic stop must be realized to reduce the costs for electricity for pumps. There is also no heat meter and so no accommodation, control and (if necessary) accounting for the building.

*Bldg 57 – Motor Pool*

The station supplies the building with heat for:

- a radiator
- domestic hot water.

The existing control on the secondary system controls the two heating circuits according to the outdoor temperature and the demand. The mentioned direct transfer station has essential fittings that are important for a safe supply, like:

- pressure reduction
- volume/differential pressure regulator
- shut-off valves/dirt arrester.

*Notes for the Substation*

At an outdoor temperature of approximately +25 °C (77 °F) the heating circuit for Bldg 57 was in operation. This should be checked because there was no shutdown of the installation.

There is also no heat meter and so no accommodation, control, and (if necessary) accounting for the building.

*Bldg 25 – Gym*

The station supplies the building with heat for:

- a radiator
- domestic hot water.

The existing control of the secondary system controls the two heating circuits according to the outdoor temperature and the demand. The mentioned direct transfer station has essential fittings that are important for a safe supply, like:

- pressure reduction
- volume/differential pressure regulator
- shut-off valves/dirt arrester.

*Notes for the Substation*

There was also a heating pump in operation at an outdoor temperature of approximately +25 °C (77 °F), which was not shut off by the control. A check is necessary to reduce the costs for electricity.

The substation has a heat meter and so the heat demand can be allocated to this building.

*Bldg 4a – Hangar*

The station supplies the building with heat for:

- a radiator
- a ventilation system
- domestic hot water.

The existing control of the secondary system controls the two heating circuits according to the outdoor temperature and the demand. The mentioned direct transfer station has essential fittings that are important for a safe supply, like:

- pressure reduction
- volume/differential pressure regulator
- shut-off valves/dirt arrester.

*Notes for the substation*

There was no claim in this installation excepting a missing heat meter (no accommodation of the heat demand [Figure 41]).


Figure 41. Substation of Bldg 4a (hangar).

*Main Station (MVV Mannheim)*

The existing main station of the local utility MVV Energie AG corresponds to the state of the technology. It consists of all necessary components for a heat supply (Figure 42).

The control and also the measurement of the consumption for a part of the Coleman Barracks take place at the main station. There is a further supply station installed similarly.

In sum they could transfer a capacity of approximately 17 MW and supplies 141 substations.

*Solution*

Do not run the pumps when not needed (i.e., in the summertime).


Figure 42. Main station of the energy supplier MVV Mannheim.

*Savings*

In four of the six visited substations heating pumps were in operation at an outdoor temperature of approximately +25 °C (77 °F). Approximately a total of 90 pumps in 141 substations could be in operation. Based on these observations, the following reduction of the costs for electricity would be possible.

The summertime in Germany is estimated to be approximately 90 days.

Pump runtime (summer) = 90 days * 24h = 2,160 h

$P_{work}$ (consumption)= 2,160 h * 90 pumps * 0.7kW/pump = 136,080 kWh

Savings = 136,080 kWh * €0.20 /kWh = €27,216/yr

*Absence of heat meters*

The total measurement for the accounting takes place in the main station of the MVV Mannheim. Therefore the heat loss of the network inside the Coleman Barrack is paid by the occupant.

No conclusion concerning possible savings could be made because the contract for delivery is not known.

It should also be noted that if buildings were rented in the near future, heat meters must be retrofitted. The heat loss of the internal district heating system is paid by the renter because the accounting takes place at the main station. In this case, the contract for delivery should possibly be modified.

*Investment costs*

It would be necessary to contract a company that deals with pump regulation to resolves the problem of non-stop operation, and to stem the waste of electricity (and associated costs) in the substation heating pumps.

Assuming that it takes 4 working hours to the check each installation, the total cost for all 141 installations would be about €45,000.

*Payback*

The resulting payback period for a new pump regulation for all 141 substations is about 1.7 yrs.

### LI #3CO – Use occupancy sensors to turn off lights

*Existing conditions*

At the Coleman Barracks buildings a number of spaces used throughout the day with high and low periods of occupancy (Figure 43). During site visits, these buildings were found to have overhead lights left "on" in unoccupied areas. Examples of spaces found vacant with the lights on were restrooms, storage areas, and a number of spaces in the administrative buildings. Many of these lights could be shut off to save electricity.

Figure 43. Empty space with light on.

*Solution*

In spaces where use varies depending on the time and current activity, the lighting system can be best controlled by occupancy sensors. These occupancy sensors can be installed that automatically switch lights on when human movement is sensed. The lighting level will be maintained until a set period of time has elapsed with no human movement observed. A period of 5 to 10 minutes would be adequate to ensure the space is truly unoccupied.

Such lighting controls should be placed in all buildings at Coleman Barracks that have varied use patterns. These spaces should also have fluorescent lighting since the time for the bulb to light is almost instantaneous. Lighting systems using sodium vapor mercury vapor or metal halide lights take several minutes for measurable light to be produced after energizing the bulb and thus are not conducive to occupancy sensor control. If the lighting in these spaces is not better controlled, this energy waste will continue.

*Savings*

Table 14 lists summary data on the savings potential based on the spaces visited. The total estimated energy cost savings is $2,021/yr.

*Example calculation – Bldg 24 Restroom*

Electrical savings = four fixtures * 0.054kW/fixture * 39.5 hr/wk * 40%
* 52 wk/yr = 177 kWh/yr

Electrical cost savings = 177 kWh/yr * €0.0893/kWh = €15.80/yr

Table 14. Savings potential of using occupancy sensors to turn off lights.

| Bldg | Space | Lights (W) | No. lights | hrs/wk | % Off | hrs off /wk | kW Saved /yr | Cost Saved | Sensor Cost | Payback Period |
|---|---|---|---|---|---|---|---|---|---|---|
| 24 | Restroom | 54 | 4 | 39.5 | 40% | 15.8 | 177 | 16 | 200 | 12.6 |
| 25 | Restroom | 32 | 7 | 72 | 30% | 21.6 | 252 | 22 | 200 | 8.9 |
| | Refrigerated Cabinets | 32 | 29 | 60 | 40% | 24 | 1158 | 103 | 1.0 | 9.7 |
| | Store Room | 64 | 3 | 60 | 40% | 24 | 240 | 21 | 200 | 9.3 |
| | Fitness Area | 64 | 30 | 60 | 20% | 12 | 1198 | 107 | 600 | 5.6 |
| | Lobby | 96 | 1 | 60 | 40% | 24 | 120 | 11 | 200 | 18.7 |
| | Classrooms | 64 | 36 | 66 | 30% | 19.8 | 2372 | 212 | 600 | 2.8 |

| Bldg | Space | Lights (W) | No. lights | hrs/wk | % Off | hrs off /wk | kW Saved /yr | Cost Saved | Sensor Cost | Payback Period |
|---|---|---|---|---|---|---|---|---|---|---|
| | Band Area Basement | 64 | 9 | 60 | 50% | 30 | 899 | 80 | 450 | 5.6 |
| | Shower Room | 64 | 2 | 60 | 30% | 18 | 120 | 11 | 600 | 56.1 |
| | Office | 64 | 6 | 60 | 25% | 15 | 300 | 27 | 200 | 7.5 |
| 57 | Office | 64 | 4 | 60 | 25% | 15 | 200 | 18 | 200 | 11.2 |
| | Shop | 64 | 6 | 60 | 30% | 18 | 359 | 32 | 200 | 6.2 |
| | Shop | 64 | 8 | 60 | 30% | 18 | 479 | 43 | 200 | 4.7 |
| 53 | Bathroom Area | 64 | 8 | 168 | 30% | 50.4 | 1342 | 120 | 600 | 5.0 |
| | Room 12 | 64 | 7 | 60 | 30% | 18 | 419 | 37 | 200 | 5.3 |
| | Room 11 Machine Shop | 64 | 31 | 60 | 30% | 18 | 1857 | 166 | 1000 | 6.0 |
| 4 | Room 4A | 64 | 3 | 60 | 30% | 18 | 180 | 16 | 200 | 12.5 |
| | Room 2c | 64 | 8 | 60 | 30% | 18 | 479 | 43 | 200 | 4.7 |
| | Room 4A | 64 | 3 | 60 | 30% | 18 | 180 | 16 | 200 | 12.5 |
| | Room 2 | 64 | 66 | 60 | 30% | 18 | 3954 | 353 | 1200 | 3.4 |
| 4 | IMP Shop | 64 | 66 | 60 | 30% | 18 | 3954 | 353 | 1200 | 3.4 |
| | Room 13 Plating | 64 | 8 | 60 | 30% | 18 | 479 | 43 | 200 | 4.7 |
| | Tool Crib | 64 | 32 | 60 | 30% | 18 | 1917 | 171 | 1200 | 7.0 |
| *Totals* | | | | | | | *22,633* | *2,021* | *11,050* | *5.5* |

*Investment*

The cost to install an infrared, wall-mounted occupancy sensor in the lighting switch is €200 each for a simple replacement of the light switch. Where a remote sensor may be needed, a higher cost is given. The total investment of the visited spaces identified in this ECM is €11,500.

*Payback*

The payback for lighting controls in the subject buildings is 5.7 yrs. It is recommended that occupancy sensors be placed in all similar spaces that have fluorescent lighting.

**LI #4CO – Change bulbs in exit lights**

*Existing conditions*

The exit signs in many of the buildings are equipped with ordinary fluorescent lights that use approximately 16W of energy (Figure 44). These lamps have an estimated life 7,500 hrs. These lamps were found in many of the buildings visited as noted in Table 15.


Figure 44. Exit sign that should be switched to a LED type.

*Solution*

The fluorescent lighted exit signs can be replaced with ones that use a more efficient LED lamp, which also has a longer life. An LED lighted exit sign that uses 5W or less should be used to replace all the fluorescent lighted exit signs in the buildings.

*Savings*

The LED exit light provides a savings of 10W to 11W and the sign is illuminated continuously for 8760 hrs/yr. The LED also has a life of over 10 yrs where the fluorescent lamp must be replaced approximately every 10 months.

Table 15. Calculated savings of replacing fluorescent exit light with LED lights.

| Bldg | Lights Watts Saved | No. lights | hrs/wk | kWh Saved /yr | Electrical Cost Savings | Lamp Cost | Old Lamp Life. yrs | Annual cost Replacement | Annual O&M Cost | LED Cost | Payback Period |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 25 | 10 | 24 | 168 | 2097 | €187 | €15 | 0.83 | €360 | €547 | €2,400 | 4.4 |
| 51 | 10 | 4 | 168 | 349.4 | €31 | €15 | 0.83 | €60 | €91 | €400 | 4.4 |
| 53 | 10 | 7 | 168 | 611.5 | €55 | €15 | 0.83 | €105 | €160 | €700 | 4.4 |
| 45 | 10 | 3 | 168 | 262.1 | €23 | €15 | 0.83 | €45 | €68 | €300 | 4.4 |
| 4 | 10 | 10 | 168 | 873.6 | €78 | €15 | 0.83 | €150 | €228 | €1,000 | 4.4 |

The savings for a single fixture is = 10W * 8760 hrs/yr = 87.6 kWh/yr

The electrical cost savings = 87.6 kWh/yr * €0.0893/kWh = €7.82/yr

There is also a savings due to the longer lamp life. A fluorescent replacement lamp will cost approximately €5.00 and the labor of this replacement is estimated to be ¼ hr.

Fluorescent lamp replacement cost = (€5 + 0.25 * €40)
 * 8760 hrs/yr/7500 hrs bulb life = €17.52/yr

LED lamp replacement cost = (€50 + 0.25 * €40)
 * 8760 hrs/yr/100,000 hrs bulb life = €5.26/yr

The replacement bulb cost savings of the LED bulb is approximately €12.00/yr

The total annual saving per exit sign of the LED bulb is approximately €20.00/yr

There are an estimated 24 exit signs in Bldg 25 and the total savings for replacing these exit lamps is €360/yr. There are many more exit signs at this site that should be replaced. Table 15 addresses the replacement of the exit signs that fluorescent lamps found during the site survey of Coleman Barracks. Assuming that this installation has total of 400 exit sign, the total savings would be €8,000/yr. It is recommended that all exits signs be upgraded.

*Investment*

LED replacement kits are available at a cost of approximately €50. This kit has all the necessary hardware to convert a fluorescent exit sign to one lit by a LED. The labor to make this conversion is approximately 1 hr. Using a cost of €40/hr for labor, the cost to switch a fluorescent exit sign to a LED type is €90. Using the 400 exit sign number from above, the total cost of this project is €36,000.

*Payback*

The payback for LED exit lights is 4.5 yrs. It is recommended that all fluorescent exit lights be replaced with a LED type.

### LI #5CO – Reduce lighting using daylighting controls — Band Lobby Area Bldg 25

*Existing conditions*

In the Lobby of the Band Administration area of Bldg 25 there are three fluorescent lights. There are a number of windows that allow natural light to illuminate this area. All the lights in the Lobby were left ON even though the natural light was adequate. The lights in this area could be turned off with no significant reduction in lighting levels. Based on the building use, it is estimated that these lights are currently on 62.5 hrs/week.

*Solution*

A lighting level sensor can be installed in the Lobby that would monitor the amount of light entering through the windows. The sensors then could turn off the fluorescent lights to save energy if it is bright enough outside.

*Savings*

It is estimated these three lighting fixtures could be turned off for 40 percent of the time the building is occupied. The estimated electrical savings is 250 kWh/yr:

Electrical savings = three fixtures * 0.064 kW * 40% * 62.5 hr/wk
* 52 wk/yr = 250 kWh/yr
Electrical cost savings = 250 kWh/yr * €0.0893/kWh = €22/yr

*Investment*

The cost to install a photocell light sensor to switch off excess lights is approximately €400 each.

*Payback*

The payback for lighting controls in the Lobby area is 18.1 yrs.

### LI #6CO – Reduce lighting using daylighting controls — Storage Area Bldg 49

*Existing conditions*

In the storage area of Bldg 49 there are transparent panels located in the upper part of the wall that allow a significant amount of natural light enter the space below (Figure 45). These panels are at either end of the building in the truss area. The lighting system used in the building is a fluorescent type that has five rows of lights with three 4-ft bulbs in each of the 14 bays of the building. There are no light level sensors in this space and the lights operate during the occupied hours of the buildings. Currently the building is operated 54 hrs/week.

Figure 45. Transparent panels in end of building with all lights ON.

*Solution*

Enough natural light enters the building through the transparent wall panels to allow the four bays of lighting nearest the walls to be shut off during sunny days. This applies to both ends of the building. Light sensors would need to be installed to control these fluorescent lights such that lamps can be turned off when lighting levels exceed recommended levels due to the natural light coming in from outside.

*Savings*

In Bldg 49 it is estimated that four bays of lights from both ends of the building could be turned off for 40 percent of the operating hrs. The estimated electrical savings is 4,310 kWh/yr:

Electrical savings = three fixtures * 0.032W * eight bays * five rows * 40%
* 54 hr/wk * 52 wk/yr = 4,310 kWh/yr
Electrical cost savings = 4,310 kWh/yr * €0.0893/kWh = €385/yr

*Investment*

The cost to install a photocell light sensor to switch off excess lights is approximately €500 each, which would require 2250 ft of #10 wire. There are five rows of lights each requiring about 450 ft of wire to connect the dimmer to the electrical box that controls each row of lights. From Means the cost of running #10 wire is $535/100 ft. Double was used this since the work is at a very high height. Adding another $10,000 for electrical boxes, rewiring existing lighting circuits, etc., the sum of $34,000 was multiplied by 150 percent to cover Contractor overhead and profit, Corps of Engineers mark-ups, etc. This results in $61,000, to which $3,000 is added for a total of $64,000.

*Payback*

The payback for lighting controls in the Bldg 49 is over 166 yrs.

### LI #7CO – Shut off outdoor lighting in daytime — Bldg 57

*Existing conditions*

During the site survey, six exterior low pressure sodium lights were observed to be on during the daytime. They are located above each of the doors that vehicles use to enter the building. These lights could be turned off to save electrical energy.

*Solution*

Install a photo-cell light sensor to turn off the lights in the daytime. Failure to install this sensor will allow electrical energy to be wasted powering the unneeded lights in this area.

*Savings*

There are six outdoor low pressure sodium lights at Bldg 25, estimated to be 55W each. Turning these lights off during the daylight hours will save 1,235 kWh/yr:

Electrical savings = six fixtures * 0.055W * 72 hr/wk * 52 wk/yr = 1,235/yr

Electrical cost savings = 1,235 kWh/yr * €0.0893/kWh = €110/yr

*Investment*

It appears that the lights are on a single circuit. The cost of a sensor is approximately €50 and installation €250.

*Payback*

The simple payback for lighting controls in the Bldg 57 is 2.7 yrs.

### LI #8CO – add skylights — Bldg 49

*Existing conditions*

No natural light enters the workspace in the vehicle maintenance portion of Bldg 49 (Figure 46). All the lights are kept on during the hours of occupancy and the spaces are still reasonably dark. This is single story buildings that could easily have skylights installed in the roof.

*Solution*

Place Two rows of three skylights in Bldg 49. Each skylight will be approximately 40x4-ft in size. Install photo cell lighting level sensors in these areas to measure the amount of daylighting being provided by the sky lights. If ample light is provided, then some or all of the lamps in the area can be turned off.

Figure 46. Maintenance area with no skylights.

*Savings*

The installation of sky lights will allow the existing lighting system to be off 40 percent of the time. The total estimated energy cost savings is €1.290/yr:

Electrical savings = 40 fixtures * 0.064W * five rows * 40% * 54 hr/wk
* 52 wk/yr = 14,400 kWh/yr

Electrical cost savings = 14,400 kWh/yr * €0.0893/kWh = €1,290/yr

*Investments*

The estimated cost to install two rows of three 4x30-ft sky lights in Bldg 49 is €51,000.

*Payback*

The resulting payback is 40 yrs.

### DIN #2CO – Modify kitchen hoods with end skirts and temperature-controlled exhaust — Bldg 45

*Existing conditions*

The Dining Hall Facility located in Bldg 45 was undergoing a major renovation during the time of the site visit. Since the floor in the kitchen was being replaced, access to the kitchen area was not possible. The dining facility operates from 530 hrs until 1900 hrs, every day of the week. When the cooking staff arrives at the building, the exhaust hoods are turned on. They are turned off when they leave for the day and thus they operate 13 hrs/day. Since the actual hood sizes for this Dining Facility are unknown, the following analysis taken from another dining facility was be used to illustrate the savings potential.

The hoods used in the kitchen of the Dining Facility would be a standard canopy type that most likely will be placed against a wall (Figure 47). Assume there are three hoods that are an average of 12 ft (3.7 m) long and 4 ft (1.2) wide. For medium duty use, the exhaust rate of such a canopy hood against a wall is 300 CFM/linear ft of hood:

Q = 300 CFM/ft * 12 ft = 6,000 CFM

Figure 47. Typical kitchen hood with no extensions down or skirts at ends.

The hoods are located 3½ ft (1.1 m) above the cooking surface. Given the hood size, the three hood exhaust systems would each remove 3,600 CFM (1,690 L/s) for a total exhaust of 10,800 CFM (5,070 L/s) of air.

The kitchen hood ventilation system is a large energy user. First there is an electrical use of operating the exhaust fan motors. There is also a supply air system that must operate to deliver make-up air for the hood exhaust. There is an electrical use to power these fans. In the winter, heat is required to temper the supply air to avoid cold spots in the kitchen.

*Solution*

The exhaust air from the kitchen hoods can be made to perform more effectively by adding skirts or wings on the left and right sides of each hood. These skirts would in essence extend the hood sides lower to better encapsulate the kitchen cooking devices that have been placed under the hood. This would allow for better capture of the cooking fumes by the hood and the exhaust air flow could be slightly reduced due to this performance improvement. The appliances should also be placed as close to the rear wall as possible to improve fume capture. The space between the appliance and the wall should be closed off with a metal panel for best performance.

Once the skirts and the metal panel placed behind the appliances are added the hood exhaust system air flow would need to be readjusted by testing the hood's performance. Issues such as room air movement can negatively affect hood performance so the new air flow rates would need to take those site conditions into account when making reductions in hood exhaust air flow.

These hoods operate during the working hours of the kitchen. These hoods continue to exhaust air even though there is no cooking occurring under them. Thus the hoods operate when they do not need to operate and energy is wasted. Sensors can be placed on the exhaust system that will allow varying the air flow. An optic sensor in the hood will monitor the presence of smoke and cooking vapors (Figure 48). A temperature sensor placed in the duct attached to the hood will note an increase in temperature. The start of cooking activities under the hood will provide a positive indication by either of these sensors and the exhaust air flow will be increased.

If the hood skirts and cooking sensors are not added the kitchen hoods would exhaust a higher air flow than needed, which relates to an excessive amount of energy use.

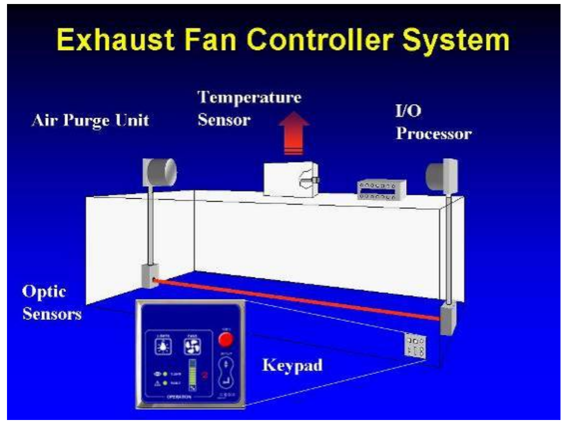

Figure 48. Exhaust fan controls.

*Energy Savings*

**Hood skirts**

It is estimated that adding skirts to the kitchen hoods and metal panels behind the appliances would allow a 10 percent reduction in exhaust air flow while achieving the same current hood capture performance.

The estimated total horsepower required by the exhaust air fans is 9 hp and that of the supply air system is 5 hp. A reduction of 10 percent air flow has a motor horsepower equal to the cube of that reduction or 0.9 X 0.9 X 0.9 = 73 percent, which is a saving of 3.8 hp for the supply and exhaust systems. Table 16 lists the calculated savings associated with adding skirts to the kitchen hoods and metal panels behind the appliances.

Table 16. Calculated savings associated with adding skirts to the kitchen hoods and metal panels behind the appliances.

| Hood Size | Exhaust Air. CFM | Estimated Motor Hp | Operating hrs/wk | Reduced Air Flow | Motor Hp Savings.% | Low Flow % of Time | kWh Saving/Yr |
|---|---|---|---|---|---|---|---|
| 12 X 4 | 3600 | 3 | 91 | 3240 | 27% | 100% | 2859 |
| 12 X 4 | 3600 | 3 | 91 | 3240 | 27% | 100% | 2859 |
| 12 X 4 | 3600 | 3 | 91 | 3240 | 27% | 100% | 2859 |
| *Totals* | *10800* | | | *9720* | | | *8578* |

Fan motor power reduction = 3.8 hp * 0.746 kW/hp * 91 hrs/wk
* 52 wk/yr = 2.8 kW * 4.732 hrs/yr = 13,400 kWh/yr.

Electrical cost savings= 13,400 kWh/yr * €0.0893/kWh = €1,200/yr

Heating savings = 1.08 * 10,800 CFM * 10% * 5,133 degree days
* 24 hr/day * 13hrs/24 hrs = 78 million Btu/yr or 22.8 $MWh_{th}$/yr

Heating cost savings =22.8 $mWh_{th}$ * €36.8/MWH = €840/yr

The total estimated cost savings of the hood skirts is €2,040/yr

**Cooking sensors**

Each kitchen hood has cooking operations occurring under it for an estimated 7 hrs/day. Thus for 6 hrs/day the hood's air flow could be reduced from 3,240 CFM to a flow of approximately 1,620 CFM for each hood. This would provide a reduced horsepower use equal to the cube of 3,450/5,900 or approximately 20 percent of the 7.5 hp when motor losses are included. The savings difference if the previous ECM is implemented is 53 percent of the motor electrical use over the 6 hrs/day or 42 hrs/week. Table 17 lists calculated savings associated with reducing the air flow in kitchen hoods.

Table 17. Calculated savings associated with reducing the air flow in kitchen hoods.

| Hood Size | Exhaust Air. CFM | Estimated Motor Hp | Operating hrs/wk | Reduced Air Flow | Motor Hp Savings.% | Low Flow % of Time | kWh Saving/Yr |
|---|---|---|---|---|---|---|---|
| 12 X 4 | 3240 | 3 | 91 | 1620 | 53% | 46% | 2582 |
| 12 X 4 | 3240 | 3 | 91 | 1620 | 53% | 46% | 2582 |
| 12 X 4 | 3240 | 3 | 91 | 1620 | 53% | 46% | 2582 |
| *Totals* | *9,720* | | | *4,860* | | | *7,746* |

Fan motor power reduction(supply and exhaust) = 14 hp * 0.53 * 0.746 kW/hp
* 42 hrs/wk * 52 wk/yr = 12,000 kWh/yr.

Electrical cost savings= 12,000 kWh/yr * €0.0893/kWh = €1,070/yr

Heating savings = 1.08 * 9720 CFM * 50% * 5,133 degree days * 24 hr/day
* 6 hrs/24 hrs = 162 million Btu/yr or 47.3 mWh/yr

Heating cost savings = 47.3 $mWh_{th}$ * $36.8/$mWh_{th}$ = €1,740/yr

The total estimated cost savings of varying the hood exhaust when not cooking is €2,810/yr.

*Investment*

The estimated cost to provide 4 x 4-ft long skirts to each side of the three hoods and a metal panel behind the cooking appliances is €6,000. The estimated cost to provide temperature and smoke detectors and the controls to adjust fan speed for the exhaust and supply air system is approximately €19,200. The cost to have variable speed drives for the three 3 hp motors and 5 hp motor is €15,400 for a cost of €34,600. The total installation cost is estimated to be €40,600

*Payback*

The resulting payback period of the side skirts is 2.9 yrs and 12.3 yrs for the varying exhaust air controls. The payback period for the installation of both is 6.5.

Based on this analysis, side curtains, rear metal panels, and exhaust hood variable air flow controls should be installed on the hoods located in Bldg 45 if the exhaust fan horsepower is greater than the estimated 3 hp. Additional analysis will be needed to identify the specific savings and cost for this facility.

### DIN #3CO – Use low flow pre-rinse kitchen nozzles

*Existing conditions*

The Dining Hall Facility located in Bldg 45 was undergoing a major renovation during the time of the site visit. Since the floor in the kitchen was being replaced access to the kitchen area was not possible. The dining facility operates from 530 hrs until 1900 hrs, every day of the week. There may be an opportunity to save hot water by using low flow dish pre-rinse scrubbing nozzles. The standard nozzle has a flow rate of 4.5 gal/minute (gpm). Low flow nozzles are available with a flow as low as 1.15 gpm.

*Solution*

Use low flow pre-rinse kitchen nozzles where scrubbing of food particles is needed. This applies to the dish washer operation and to the pots and pans wash area. Here high flow pre-rinse nozzles may be used to scrub off food. Low flow pre-rinse nozzles are available that have high pressure water jet action for this in these application. Replace all high flow pre-rinse nozzles with low flow types. If the kitchen nozzles are not replaced with low flow types, an excessive amount of hot water will be used.

*Energy savings*

A standard pre-rinse nozzle has a flow of 4.5 gpm and a low flow nozzle type uses 1.15 gpm for a saving of 3.35 gpm. Using an estimated use time of 3 hrs/day the low flow nozzle will save approximately 220,000 gal of hot water/yr:

Heating savings = 1Btu/lb/°F * 3.35 gpm * 8.3 lb/gal * (140 – 60)°F
* 60 min/hr * 3 hrs/day * 365 day/yr = 146 million Btu/yr or 42.8 $mWh_{th}$/yr

Heating cost savings =42.8 $mWh_{th}$ * €36.8/MWH = €1,560/yr

*Investment*

The estimated cost of a low flow pre-rinse nozzle is €80 each, which includes 15 minutes labor charge for someone to change the nozzle.

*Payback*

The resulting payback period of the low flow nozzles is 3 wks.

### HVAC #5CO – Reduce pressure and recover waste heat from air compressor — Motor Pool Bldg 57

*Existing conditions/problems*

In a back room of the Motor Pool Bldg 57 at Coleman Barracks is a piston type compressor. It supplies the Motor Pool with compressed air. According to the sergeant in charge of the facility, the needs are to have 120 psig pressure, which is equivalent to 8.3 bars. At the time of the EEAP assessment, the compressor generated 12 bar pressure. The compressor has a 22 kW motor.

*Solution*

Reduce the pressure to 9 bars (a 25 percent reduction). Install a temperature-controlled fan in the compressor room that starts whenever the unit heaters in the Motor Pool get the signal from the thermostat to start supplying heat. The recovered heat from the compressor room will save energy for heating and will also provide more comfortable working conditions for the compressor itself.

*Savings*

Reducing the pressure will reduce the energy used by the compressor by at least 25 percent. Assume that the compressor is used 8 hrs/day on weekdays and that it is turned off during weekends. Also assume that it is 25 percent loaded. The annual energy use then is:

22 kW * 0.25 * 8 hrs/day * 5 days * 52 wks = 11,440 kWh/yr. Savings
(25% by reducing the pressure is equivalent to 2,860 kWh or €260/yr.)

The energy that can be recovered is useful only during the heating season assumed to be between October – April (29 wks/yr). The available energy then (after pressure reduction) is:

0.75 * 11,440 kWh * 29/52 wks = 4,800 kWh

This recovered energy replaces heat. Based on natural gas the savings are:

4,800 kWh/0.8 (boiler efficiency) * €0.0368 /kWh = €220 /yr.
Total savings = €460/yr

*Investment*

To change the pressure set point for the compressor does not require any investment. Installing a temperature-controlled fan with some intelligent controls to make it operable together with the unit heaters is estimated to cost less than €1,000.

*Payback*

The resulting payback will occur within 2.1 yrs.

**HVAC #6CO – Optimize the use of compressed air and the sizing of the air compressors — Hanger Bldg 4**

*Existing conditions/problems*

Bldg 4 at Coleman barracks has a Kaeser DSB220 from 1982 with a 132 kW motor. This compressor is far too large for the current use of compressed air. It was noted that the units have been running quite a lot. A runtime meter indicated that the compressor had 15,210 hrs total time and 4,177 hrs loaded. A screw compressor that runs unloaded uses approximately 50 percent of the power that is used when it is loaded.

*Solution*

1. Disconnect the presently used air compressor. Do not ever use it again. Buy a new air compressor that is sized approximately 40 percent of the size of the present compressor.

2. Question the use of every single air-driven tool. There are electric alternatives available, widely used in European manufacturing industry. Try to get rid of as many as possible of these tools since the use of compressed air is so energy inefficient.
3. Examine the possibilities to switch off the air compressor at nights and weekends when no one works. Are there pieces of equipment that needs the system to be pressurized? If not, switch the compressors off during periods when the buildings are not occupied.
4. Search the compressed air distribution for leaks at least every 4 months, preferably by using an ultra-sound leak detection device. Fix all identified leaks.
5. Consider ducting the heat from the compressors in through the walls into the motor pool area and the hangar respectively in winter to help heating the buildings. Make sure that the heat can be ducted to the outside in the summer when there is no need for heat.

*Savings*

The compressor uses approximately 132 kW when loaded and 66 kW when unloaded. Using these values and the run time meter readings gives over 72 percent of the daily hours in unloaded mode with no air being compressed. During the 250 working days of the yr, the un-productive energy use adds up to:

66 kW * 0.72 * 8 hrs/day * 250 days = 95,000 kWh.

In addition to this, unloaded hours during nights and weekends add to the electric energy waste another estimated 15,000 kWh, just to keep the system pressurized.

The different steps proposed above will lead to total savings that are larger than this since elimination of air-driven tools and a preventive leak detection program will also reduce the hours when the new compressors will run loaded; therefore the total annual energy savings are estimated to be in the range of 130,000 kWh, worth €11,600/yr.

If it is decided that also the heat from the compressor should be used the additional savings makes this an even more interesting ECM.

*Investment*

A new small compressor at Coleman costs approximately €25,000.

*Payback*

The resulting payback will occur within 2.2 yrs (not including heat recovery savings).

### HVAC #7CO – Replace pneumatic controls with DDC —Bldg 4

*Existing conditions/problems*

Some buildings at the German Army installations have old pneumatic controls. Bldg 4 at Coleman Barracks in Mannheim is such a building.

*Solution*

Replace old pneumatic systems with direct digital control (DDC) controls. They have far fewer moving parts than a pneumatic system. An automated DDC system replaces air-operated sensors and controllers with electronic sensors and microprocessor based controls that constantly monitor variables such as temperature, humidity, and pressure and command electric motors to automatically open or close valves for adjustments to the process variable (value to be controlled such as space temperature). DDC controls also reduce maintenance time and expenses while increasing energy efficiency.

*Savings*

A DDC system provides many benefits such as lower energy use, finer temperature control, flexibility in sequences of operation, lower maintenance costs, and graphical displays of systems from a central location. The ability to measure very small increments of flow and flow changes allows the system to automatically fine-tune room or area temperatures.

Further savings are evident by the system's flexibility. Facility managers and building engineers can easily input and change HVAC conditions. The system then commands the HVAC system to follow the programmed setpoints. For instance, for a weekend basketball game (when a school is normally closed), the engineer can enter the date, hours, and the areas (the gym and locker rooms) requiring the HVAC system to be operational. The rest of the building can remain shut down. Computer enhancements help create a non-intimidating user-friendly environment. Many DDC systems offer simplified procedures to easily change standard set-points and schedules, daylight savings time, and weekend schedules. Since DDC systems are designed with minimal moving parts, they experience far fewer mechanical failures and require less maintenance than pneumatic systems.

Finally, a DDC system can generate reports that measure and record energy consumption, service call activity, and the maintenance schedule. These valuable resources help justify cost analysis and support corporate strategies. When considering additional pneumatic facility conversions, use the data analysis from the reports for forecasting costs and savings.

Replacing pneumatic controls with DDC greatly reduces energy bills. Annual savings of approximately 15 percent are not uncommon based on previous experience. Using Bldg 4 at Coleman Barracks as an example with an estimated energy use for heating of 4,000 MWh heating, and (assuming that most parts of the building are controlled by pneumatic controls) will give savings of:

15% * 4,000 = 600 MWh heating (€22,000)

*Investment*

Replacing a pneumatic controls system with DDC controls is quite costly since all sensors, actuators etc. must be replaced. As a rule of thumb, it can be stated that most DDC controllers and components cost less than current analog devices. The investment cost must be developed from case to case and compared to the actual possible savings. Although the systems are scalable and modular it cannot be neglected that it is more cost efficient to start with large buildings with large energy use. The installation should start with the parts of Bldg 4 that still have pneumatic controls. The investment in this case is estimated to be around €150,000.

*Payback*

Payback depends on the actual building and the systems therein. In this case, payback will occur within 6.8 yrs.

### REN #1CO – REN #9CO – Photovoltaics at Coleman Barracks — Mannheim

*Existing Conditions*

At Coleman Barracks, Mannheim eight buildings closely identical in construction with optimal orientations and inclinations and a large flat roof of the Gymnasium were evaluated (Figure 49). There is no Open Space in Mannheim/Coleman Barracks for free-standing ground-placed PV-Systems.

All calculations are to be seen as orientations within a bandwidth of ±5 percent. Cable length, specific construction issues, inclination data, PV-areas of the roof, and the number of modules are in some cases estimated figures and due to these estimates the results per building may change within this bandwidth.


Figure 49. Coleman Barracks Mannheim with marked buildings.

No site plan of Coleman Barracks was delivered, but the new technologies offers more realistic pictures than site plans do. In Figure 49, all buildings with PV-potential are marked. Bldg 25 (the Gymnasium) has a nearly flat roof. The roof construction is very stable. A free-standing PV-System can be applied to that roof.

Eight Bldgs (11, 13, 15, 17, 29, 31, 33, 35) are nearly identical in construction. The lengths of the buildings differ by maximum of 20 m. For the detailed calculations one typical building will be designed. The roof windows are reducing the available area for PV-System. In the calculations, only 60 percent of the total roof area is taken as a calculation base for the area of the PV-System.

The selected PV-modules show its advantage in such cases because the square footage of the Würth Solar modules is smaller than at other module types.

*Barracks: Bldg 11 – 35*

Figure 50 shows and the data in Table 18 describe (Barracks) Bldg 35 in Mannheim.

Figure 50. Bldg 35/Barracks – Mannheim.

Table 18. Bldgs 11–35 PV-system/Mannheim.

| Parameter | Measure | Remarks |
|---|---|---|
| Location | Mannheim | Standardized PV-System – Calculation done for one building |
| Footprint (average) | 65 m x 18 m | |
| Roof Characteristic | Ridge Roof | |
| Inclination | 43 degrees | |
| Orientation | 180 degrees | |
| Area of PV-System (average) | 390 m² | |
| No. of Modules | 550 | |
| Output | 44.28 kWp | |
| Roof Load/m² | 17.5 kg | |
| Estimated yearly results | | |

| Parameter | Measure | Remarks |
|---|---|---|
| Specific Annual Yield | 1,010 kW/kWp | |
| Grid Feed-in/yr | 44,744 kWh | First year/Degradation: 5% in 20 yrs |
| Total Revenue (20-yr period) | €402,142 | Installation End 2008 |
| Total Revenue (20.5-yr period) | €391,810 | Installation Mid 2009 |
| Investment Cost | €201,297 | Total Investment costs including installation |
| Investment Cost/kWp | €4,546 | |
| Break even time (without capital cost) | 9/10 yrs | Installation 2008/2009 |
| Liquidity cumulated (with capital cost) | €105,906/€95,574 | Installation 2008/2009 |
| Real rate of return | 52.6%/47.5% | Installation 2008/2009 |
| $CO_2$ Reduction cumulative | 288 t/296 t | Installation 2008/2009 |

*Gymnasium Bldg 25*

Figure 51 shows and the data in Table 19 describe Bldg 25 (the Gymnasium) in Mannheim. Figure 52 shows the proposed positioning of the PV-system on Bldg 25.

Figure 51. Bldg 25/Gymnasium – Mannheim.

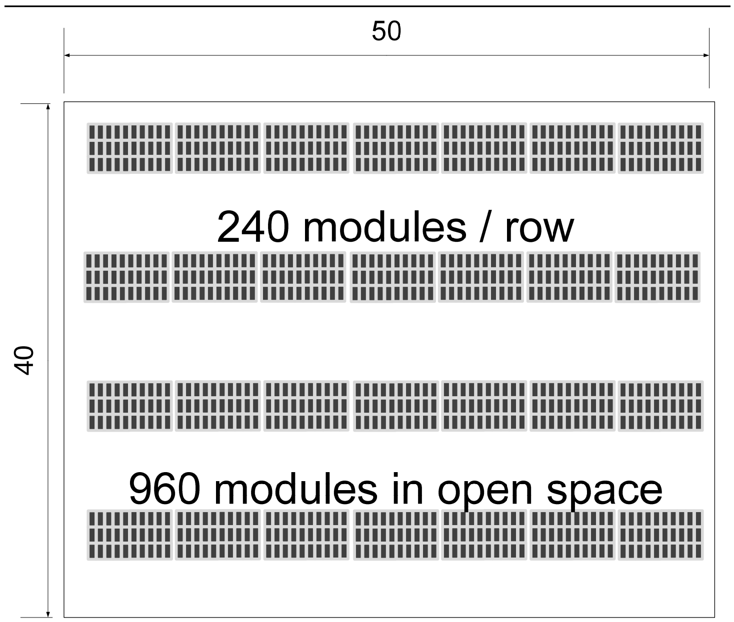


Figure 52. Bldg 25/Gymnasium – positioning PV-system.

The number of modules in the calculation is about 20 percent lower than the area of the roof will be able to carry because of the equipment placed on the roof.

Table 19. Bldg 25 – PV-system/Mannheim.

| Parameter | Measure | Remarks |
|---|---|---|
| Location | Mannheim | |
| Footprint (Approximate) | 50 m x 42 m | |
| Roof Characteristic | Flat Roof | Free-standing PV-System |
| Inclination | 35 degrees | |
| Orientation | 180 degrees | |
| Area of PV-System | 690 m² | |
| No. of Modules | 960 | |
| Output | 77.28 kWp | |
| Roof Load/m² | 19.25 kg | 10% mark up because of carrier system |
| Estimated yearly results | | |
| Specific Annual Yield | 1,017 kW/kWp | |
| Grid Feed-in/yr | 78,595 kWh | First year/Degradation: 5% in 20 yrs |
| Total Revenue (20-yr period) | €696,258 | Installation End 2008 |
| Total Revenue (20,5-yr period) | €678,396 | Installation Mid 2009 |

| Parameter | Measure | Remarks |
|---|---|---|
| Investment Cost | €368,881 | Total Investment costs including installation |
| Investment Cost/kWp | €4,773 | 5% mark up because of carrier system |
| Break even time (without capital cost) | 10/11 yrs | Installation 2008/2009 |
| Liquidity cumulative (with capital cost) | €153,401/€135,593 | Installation 2008/2009 |
| Real rate of return | 41.6%/36.7% | Installation 2008/2009 |
| $CO_2$ Reduction cumulative | 507 t/520 t | 20-yr period |

## Summary

Table 20 lists the ECMs for the Coleman Barracks.

Table 20. Summary of Coleman Barracks ECMs.

| ECM # | ECM Description | Electrical Savings | | Thermal | | Maintenance (€/yr) | Total Savings: Electrical Use, Elec Demand, Thermal, and Maint (€/Yr) | Investment (€) | Simple Payback (yrs) |
|---|---|---|---|---|---|---|---|---|---|
| | | KWh/yr | €/yr | MMBtu/yr | €/Yr | | | | |
| BE #1CO | Install Panels in Areas Having Single Pane Windows, Bldg 25 | 0 | €0 | 124 | €1,336 | €0 | €1,336 | €19,800 | 14.8 |
| BE #2CO | Reduce Door Size, Bldg 49 | 0 | €0 | 290 | €3,132 | €0 | €3,132 | €44,500 | 14.2 |
| DIN #2CO | Modify Kitchen Hoods with End Skirts and Temperature Controlled Exhaust, Bldg 45 | 25,400 | €3,629 | 240 | €2,588 | €0 | €6,217 | €40,600 | 6.5 |
| DIN #3CO | Use Low Flow Pre-rinse Kitchen Nozzles | 0 | €0 | 146 | €1,574 | €0 | €1,574 | €80 | 0.1 |
| CEP #4CO | Substation Optimization – Coleman Barracks | 136,080 | €27,216 | 0 | €0 | €0 | €27,216 | €45,000 | 1.7 |
| HVAC #5CO | Reduce Pressure and Recover Waste Heat from Air Compressor, Motor Pool Bldg 57 | 2,860 | €255 | 20 | €221 | €0 | €476 | €1,000 | 2.1 |
| HVAC #6CO | Optimize the Use of Compressed Air and the Sizing of the Air Compressors – Hanger Bldg 4 | 130,000 | €11,609 | 0 | €0 | €0 | €11,609 | €25,000 | 2.2 |
| HVAC #7CO | Replace Pneumatic Controls with DDC Bldg 4 | 0 | €0 | 2048 | €22,080 | €0 | €22,080 | €150,000 | 6.8 |
| LI #3CO | Use Occupancy Sensors to Turn off Lights | 22,633 | €2,021 | 0 | €0 | €0 | €2,021 | €11,500 | 5.7 |
| LI #4CO | Change Bulbs in Exit Lights | 34,950 | €3,121 | 0 | €0 | €4,800 | €7,921 | €36,000 | 4.5 |
| LI #5CO | Reduce Lighting Using Day Lighting Controls, Band Lobby Area, Bldg 25 | 250 | €22 | 0 | €0 | €0 | €22 | €400 | 17.9 |
| LI #6CO | Reduce Lighting Using Day Lighting Controls, Storage area Bldgs 49 | 4,310 | €385 | 0 | €0 | €0 | €385 | €64,000 | 166.3 |
| LI #7CO | Shut off Outdoor Lighting in Daytime, Bldg 57 | 1,235 | €110 | 0 | €0 | €0 | €110 | €300 | 2.7 |
| LI #8CO | Add Skylights, Bldg 49 | 14,400 | €1,286 | 0 | €0 | €0 | €1,286 | €51,000 | 39.7 |
| LI #9CO | Change Bulbs in Exit Lights | 34,950 | €3,121 | 0 | €0 | €4,800 | €7,921 | €36,000 | 4.5 |
| LI #10CO | Reduce Lighting Using Day Lighting Controls, Band Lobby Area, Bldg 25 | 250 | €22 | 0 | €0 | €0 | €22 | €400 | 17.9 |
| LI #11CO | Reduce Lighting Using Day Lighting Controls, Storage area Bldg 49 | 4,310 | €385 | 0 | €0 | €0 | €385 | €64,000 | 166.3 |
| LI #12CO | Shut off Outdoor Lighting in Daytime, Bldg 57 | 1,235 | €110 | 0 | €0 | €0 | €110 | €1,000 | 9.1 |
| LI #13CO | Add Skylights, Bldg 49 | 14,400 | €1,286 | 0 | €0 | €0 | €1,286 | €51,000 | 39.7 |
| REN #1CO | PV System Bldg 25 Coleman Barracks – Manheim | 78,595 | €34,813 | 0 | €0 | €0 | €34,813 | €368,881 | 10.6 |
| REN #2CO | PV System Bldg 11 Coleman Barracks – Manheim | 44,744 | €20,107 | 0 | €0 | €0 | €20,107 | €201,297 | 10.0 |
| REN #3CO | PV System Bldg 13 Coleman Barracks – Manheim | 44,744 | €20,107 | 0 | €0 | €0 | €20,107 | €201,297 | 10.0 |
| REN #4CO | PV System Bldg 15 Coleman Barracks – Manheim | 44,744 | €20,107 | 0 | €0 | €0 | €20,107 | €201,297 | 10.0 |
| REN #5CO | PV System Bldg 17 Coleman Barracks – Manheim | 44,744 | €20,107 | 0 | €0 | €0 | €20,107 | €201,297 | 10.0 |
| REN #6CO | PV System Bldg 29 Coleman Barracks – Manheim | 44,744 | €20,107 | 0 | €0 | €0 | €20,107 | €201,297 | 10.0 |
| REN #7CO | PV System Bldg 31 Coleman Barracks – Manheim | 44,744 | €20,107 | 0 | €0 | €0 | €20,107 | €201,297 | 10.0 |
| REN #8CO | PV System Bldg 33 Coleman Barracks – Manheim | 44,744 | €20,107 | 0 | €0 | €0 | €20,107 | €201,297 | 10.0 |
| REN #9CO | PV System Bldg 35 Coleman Barracks – Manheim | 44,744 | €20,107 | 0 | €0 | €0 | €20,107 | €201,297 | 10.0 |
| *Totals* | | *164,340* | *€31,101* | *821* | *€8,850* | *€0* | *€39,951* | *€150,980* | *3.8* |

## Katterbach Barracks, Ansbach and Storch Barracks, Illesheim

### RAD #1KS through RAD#8KS – Radiant heating Katterbach and Storch Barracks

*General*

The on-site investigation of the Ansbach/Illesheim radiant heating project was the result of the discussion in Wiesbaden at U.S. Army Corps of Engineers on 14 March 2008. Two different design and calculations were done for this project, one by the Contract Officer Representative (COR) and one by Senergy GmbH/radiaTec GmbH, which resulted in differing results. The objectives of the on-site investigation was to define on common design and calculation platform, which has to be used to work out a new and valid design and a reliable calculation for the radiant heating project in Ansbach and Illesheim.

The following remarks are valid for all buildings and represent the common understanding of all participants regarding the approach of the design and calculation of the project:

- If it is not possible to connect the new radiant heating equipment to the existing control systems, a temporary solutions for the inside and outside temperature control will be installed. These temporary solutions will be replaced during a later renewal of the existing control systems.
- In all buildings, the radiant heating equipment design (mounting) must be checked for compatibility with existing sprinkler systems.
- In the final design, statistics of all buildings must be checked to ensure that the weight of the radiant heating systems will not exceed the load capacity of the buildings. (Consider the snow load regulations.)

Buildings included:

- Ansbach 5801, 5802, 5806, and 5807
- Illesheim 6500, 6501, 6503, and 6633.

In all eight buildings, the actual situation was checked both inside the buildings and in the heating distribution facilities. Appendix D includes drawings of the radiant heating equipment design for these eight buildings.

*Heating capacity and heat requirement*

During the on-site investigation, the team estimated the heat capacity for each building. These estimates were used to design and calculate the radiant heating systems. The heating capacity and the heat requirement were cross checked and validated by using the actual consumption figures. The Senergy calculation model was based on the EnEV regulations and an empirical heat capacity factor.

The status of the documents represents more than a 35 percent design. RadiaTec delivered a complete quotation with all documents necessary to start the final design to place the order or to start the bidding procedure. Based on these documents, a project order might be placed at radiaTec directly (including all work for the final design and excluding project management tasks) or a bidding procedure might be started. Attachments to the Report, included in the electronic version, were:

- Project quotation for all buildings (radiaTec)
- Technical Details of the radiant heating system for all buildings (radiaTec)
- Drawings of the design of the radiant heating system for all buildings (radiaTec)
- Calculation of new piping/piping demolition work for all buildings (done by a subcontractor of radiaTec).

All attachments were addressed to Senergy GmbH. If the project is ordered, it will be handled directly between the U.S. Army and radiaTec.

*Radiant heating summary consumption and energy costs*

Tables 21 and 22 list energy consumption data and calculations.

Table 21. Energy consumption data.

| Bldg | District Heat FY 2005* MWh | District Heat FY 2005* € | Price/kWh | District Heat FY 2006 MWh | District Heat FY 2006 € | Price/kWh | Increase (%) |
|---|---|---|---|---|---|---|---|
| 5801 | 596 | 37,944 | 0.064 | 412 | 38,884 | 0.094 | 48% |
| 5802 | 501 | 31,927 | 0.064 | 355 | 36,931 | 0.104 | 63% |
| 5806 | 402 | 25,593 | 0.064 | 343 | 45,143 | 0.132 | 107% |
| 5807 | 1,191 | 75,825 | 0.064 | 1,288 | 94,965 | 0.074 | 16% |
| 6500 | 1,343 | 87,374 | 0.065 | 1,509 | 119,423 | 0.079 | 22% |
| 6501 | 1,139 | 74,102 | 0.065 | 1,280 | 101,283 | 0.079 | 22% |
| 6502 | 1,344 | 87,439 | 0.065 | 1,510 | 128,517 | 0.085 | 31% |
| 6633 | 420 | 27,324 | 0.065 | 472 | 40,161 | 0.085 | 31% |
| Total | 6,936 | 447,532 | 0.065 | 7,169 | 605,311 | 0.084 | 31% |

* All data were delivered by Regina Kranz. DPW Ansbach (CERL energy Assessment fiscal year (FY) 2005/2006)

Table 22. Key factors new calculation – energy consumption/radiant heating (key factors of new calculation).

| Bldg. # | Estimate Average consumption MWh | Ave Price/MWh (FY06) (€) | Estimate future energy cost (€) | Estimate saving radiation heating | Estimated Average new consumption (MWh) | Average Price/MWh (FY06) (€) | Future estimate energy costs (€) |
|---|---|---|---|---|---|---|---|
| 5801 | 504* | 84 | 42,336 | 30% | 352 | 84 | 29,568 |
| 5802 | 428* | 84 | 35,952 | 30% | 299 | 84 | 25,116 |
| 5806 | 465* | 84 | 39,060 | 30% | 325 | 84 | 27,300 |
| 5807 | 1,239** | 84 | 104,076 | 30% | 867 | 84 | 72,828 |
| 6500 | 1,426** | 84 | 119,784 | 30% | 998 | 84 | 83,832 |
| 6501 | 1,209** | 84 | 101,556 | 30% | 846 | 84 | 71,064 |
| 6502 | 1,427** | 84 | 119,868 | 30% | 998 | 84 | 83,832 |
| 6633 | 446** | 84 | 37,464 | 30% | 312 | 84 | 26,208 |
| Total | 7,144 | 84 | 600,096 | | 4,997 | 84 | 419,748 |

* Where there were large discrepancies between the two values, the average value was increased by 25 percent to establish a kind of "reserve"

**In all other cases the average value was used.

*Summary of Analysis*

- To get a realistic scenario for the energy consumption of each building the average energy consumption of the years 2005 and 2006 was determined.

- The data show that radiant heating systems can achieve approximately 30 percent energy savings. This reduction leads to the expected average energy consumption (using radiant heating systems).
- Total saving of approximately 180,000 €/yr (Table 23).
- The total energy savings in a 20-yr period are approximately €4.8M. (see Figure 53)

*Investment*

Table 23. Summary investment.

| Bldg | Radiant Heating | Mounting | Piping/new and demolition | Additional work (valves, controllers, sensors, others) | Total |
|---|---|---|---|---|---|
| 5801 | 54,000 | 20,000 | 14,000 | 15,000 | 103,000 |
| 5802 | 54,000 | 20,000 | 14,000 | 15,000 | 103,000 |
| 5806 | 110,000 | 39,000 | 26,000 | 15,000 | 190,000 |
| 5807 | 65,000 | 25,000 | 24,000 | 15,000 | 129,000 |
| 6500 | 165,000 | 60,000 | 28,000 | 15,000 | 268,000 |
| 6501 | 165,000 | 60,000 | 28,000 | 15,000 | 268,000 |
| 6502 | 165,000 | 60,000 | 28,000 | 15,000 | 268,000 |
| 6633 | 43,000 | 16,000 | 28,000 | 15,000 | 102,000 |
| *Total* | *821,000* | *300,000* | *190,000* | *120,000* | *1,431,000* |
| *Total Special Offer* | *740,000* | *260,000* | *140,000* | *60,000* | *1,200,000* |

* The third part of the building is missing in the quotation of radiaTec. Investment costs are estimated based on the figures of the other buildings

Notes:

- Total investment first quotation of radiaTec approximately €1.478 million.
- Special offer – valid until 31 July 2008
- radiaTec and its subcontractors offer an investment price of €1,200,000 for this particular project valid until 31 July 2008. This special offer has to be ordered officially by this date. The realization of the project can take place in 2008 – 2009. This time limitation of the offer is due to the expected increase of the steel prices in the second half of 2008.
- If the project is ordered after 31 July, the investment costs have to be reconsidered due to the expected increase in steel prices.

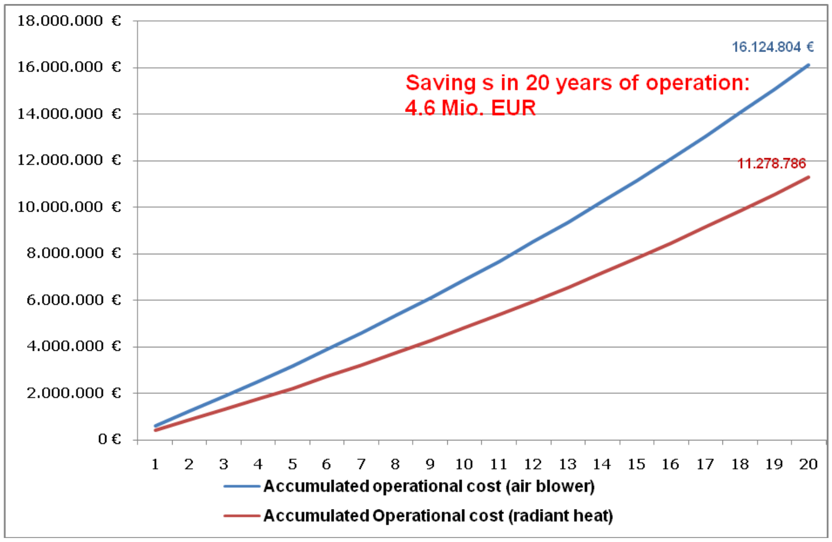


Figure 53. Accumulated operational costs – 20-yr period.

- The breakeven point calculated with the investment costs of radiaTec (€1.478 Million) will be reached in 6 yrs (see Figure 54)
- The break-even point calculated with the investment costs of radiaTec, special offer (€1.2 Million) will be reached in 5 yrs (see Figure 54)
- The return on investment/break-even point is calculated in both cases at a price increase for the district heat supply at 3 percent/yr.
- Higher increases of combustibles prices will shorten the break-even time.

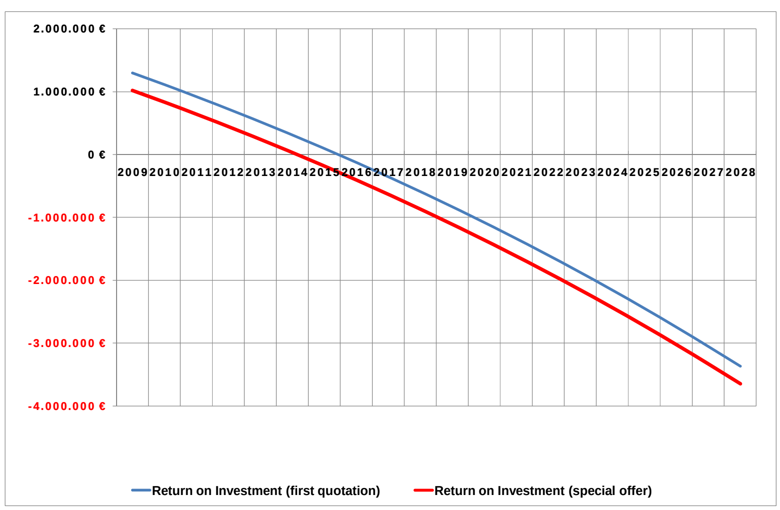


Figure 54. Break-even points.

*Buildings details*

**Bldg 5801 – Ansbach**

Figure 55 shows and the data in Table 24 describe Bldg 5801 at Ansbach. Figure D1 (on p 210 of Appendix D to this report) shows the radiant heating equipment design for Bldg 5801.

Figure 55. Bldg 5801 – Ansbach.

Table 24. Bldg 5801 – details.

| Hangar | Volume ($m^3$) | Factor ($W/m^3$) | Length | Width | Height |
|---|---|---|---|---|---|
| Building characteristics | 17,000 | 12 | 51.5 | 29.9 | 9.2/11/9.2 |
| Building Condition | Low quality insulation/Doors not insulated | | | | |
| Actual Heating System | Water-based air blowers (flow 80 °C/return 60 °C) | | | | |
| | Calculation | | | Remarks | |
| | by radiaTec | by Senergy GmbH | by Factor | | |
| Heating capacity (kW) | 170 | 178 | 204 | Only valid for radiant heating equipment | |
| Annual heat requirement (MWh) | | 364 | | | |
| Investment (rounded – accurate values see quotation radiaTec) | | | | | |
| (All values in €). | | | Remarks | | |
| Investment radiant heating equipment | 54,000 | | | | |
| Investment mounting and commissioning | 20,000 | | | | |
| Piping – new work | 6,000 | | Approximately 60 m/Price €100/m | | |
| Piping – demolition work | 8,000 | | Approximately 200 m/Price €40/m | | |
| Additional work | 15,000 | | Valves, sensors, and control equipment | | |
| Total Investment | 103,000 | | | | |

**Bldg 5802 – Ansbach**

The data in Table 25 describe Bldg 5802 – Ansbach, which is constructed similarly to Bldg 5801. Figure D2 (on p 211 of Appendix D to this report) shows the radiant heating equipment design for Bldg 5802.

Table 25. Bldg 5802 – details.

| Hangar | Volume ($m^3$) | Factor ($W/m^3$) | Length | Width | Height |
|---|---|---|---|---|---|
| Building characteristics | 17,000 | 11 | 51.5 | 29.9 | 9.2/11/9.2 |
| Building Condition | Medium quality insulation/Doors insulated | | | | |
| Actual Heating System | Water-based air blowers (flow 80 °C/return 60 °C) | | | | |
| | Calculation | | | Remarks | |
| | by radiaTec | by Senergy GmbH | by Factor | | |
| Heating capacity (kW) | 170 | 174 | 187 | For radiant heating equipment | |
| Annual heat requirement (MWh) | | 315 | | | |
| Investment (rounded – accurate values see quotation radiaTec) | | | | | |
| (All values in €). | | | Remarks | | |
| Investment radiant heating equipment | 54,000 | | | | |
| Investment mounting and commissioning | 20,000 | | | | |
| Piping – new work | 6,000 | | Approximately 60 m/Price €100/m | | |
| Piping – demolition work | 8,000 | | Approximately 200 m/Price €40/m | | |
| Additional work | 15,000 | | Valves, sensors and control equipment | | |
| Total Investment | 103,000 | | | | |

**Bldg 5806 – Ansbach**

Figure 56 shows, and the data in Table 26 describe Bldg 5806 at Ansbach. Figure D3 (on p 212 of Appendix D to this report) shows the radiant heating equipment design for Bldg 5806.

Figure 56. Bldg 5806 – Ansbach.

Table 26. Bldg 5806 (double building) – details.

| Hangar | Volume (m³) | Factor (W/m³) | Length | Width | Height |
|---|---|---|---|---|---|
| Building characteristics | 17,700 + 17,700 | 10 | 36/36 | 40.9/40.9 | 9.4/13.5/9.4 |
| Building Condition | Medium quality insulation/Doors insulated | | | | |
| Actual Heating System | Water-based air blowers (flow 80 °C/return 60 °C) | | | | |
| | Calculation | | | Remarks | |
| | by radiaTec | by Senergy GmbH | by Factor | | |
| Heating capacity (kW) | 340 | 357 | 354 | Only for radiant heating equipment | |
| Annual heat requirement (MWh) | | 315 | | | |
| Investment (rounded – accurate values see quotation radiaTec) | | | | | |
| (All values in €). | | | Remarks | | |
| Investment radiant heating equipment | 110,000 | | | | |
| Investment mounting and commissioning | 40,000 | | | | |
| Piping – new work | 22,000 | | Approximately 220 m/Price €100/m | | |
| Piping – demolition work | 6,000 | | Approximately 150 m/Price €40/m | | |
| Additional work | 15,000 | | Valves, sensors and control equipment | | |
| Total Investment | 193,000 | | | | |

**Bldg 5807 – Ansbach**

Figure 57 shows Bldg 5807-1, and Figures 58 and 59 show Bldgs 5807-2 and 5807-3 at Ansbach; the data in Table 26 describe those buildings. Figure D4 (on p 213 of Appendix D to this report) shows the radiant heating equipment design for Bldg 5807.

Figure 57. Bldg 5807-1 – Ansbach.

Figure 58. Bldg 5807-2 – Ansbach.

Figure 59. Bldg 5807-3 – Ansbach.

Table 27. Bldg 5807 (triple building) – details.

| Hangar | Volume ($m^3$) | Factor ($W/m^3$) | Length | Width | Height |
|---|---|---|---|---|---|
| Building Characteristics | 13,500 +<br>13,500 +<br>6,000 | 11 | 39.5<br>39.5<br>34.0 | 25.0<br>25.0<br>18.0 | 13.5<br>13.5<br>10.0 |
| Building Condition | low quality insulation/Doors insulated | | | | |
| Actual Heating System | Water-based air blowers (flow 80 °C /return 60 °C) | | | | |
| | Calculation | | | Remarks | |
| | by radiaTec | by Senergy GmbH | by Factor | | |
| Heating capacity (kW) | 220+90 | 329 | 363 | Only for radiant heating equipment | |
| Annual heat requirement (MWh) | | 840 | | | |
| Investment (rounded – accurate values see quotation radiaTec) | | | | | |
| (All values in €). | | | Remarks | | |
| Investment radiant heating equipment | 65,000 + 25,000 | | | | |
| Investment mounting and commissioning | 40,000 + 15,000 | | | | |
| Piping – new work | 14,500 + 5,000 | | Approximately 145 m/Price €100/m<br>Approximately 50 m | | |
| Piping – demolition work | 8,000 + 2,000 | | Approximately200 m/Price €40/m<br>Approximately 50 m | | |
| Additional work | 15,000 | | Valves, sensors and control equipment. | | |
| Total Investment | 198,500 | | | | |

**Bldg 6500 –Illesheim**

Bldg 6500 – 6503 are constructed identically (Figure 60 and Table 28). Figure D5 (on p 214 of Appendix D to this report) shows the radiant heating equipment design for Bldg 6500.

Figure 60. Bldg 6500 – Illesheim.

Table 28. Bldg 6500 (double building) – details.

| Hangar | Volume ($m^3$) | Factor ($W/m^3$) | Length | Width | Average Height |
|---|---|---|---|---|---|
| Building Characteristics | 25,000 + 25,000 | 11 | 50.0<br>50.0 | 39.4<br>39.4 | 12.7<br>12.7 |
| Building Condition | medium quality insulation/Doors insulated | | | | |
| Actual Heating System | Water-based air blowers (flow 80 °C/return 60 °C) | | | | |
| | Calculation | | | Remarks | |
| | by radiaTec | by Senergy GmbH | by Factor | | |
| Heating capacity (kW) | 580 | 591 | 550 | Only for radiant heating equipment | |
| Estimated Annual heat requirement (MWh) | | 925 | | | |
| Investment (rounded – accurate values see quotation radiaTec) | | | | | |
| (All values in €). | | | Remarks | | |
| Investment radiant heating equipment | 165,000 | | | | |
| Investment mounting and commissioning | 60,000 | | | | |
| Piping – new work | 16,000 | | Approximately 160 m/Price €100/m | | |
| Piping – demolition work | 12,000 | | Approximately 300 m/Price €40/m | | |
| Additional work | 15,000 | | Valves, sensors and control equipment. | | |
| Total Investment | | | | | |

**Bldg 6501 –Illesheim**

Bldgs 6500 – 6503 are constructed identically. The data in Table 29 describe Bldg 6501. Figure D6 (on p 215 of Appendix D to this report) shows the radiant heating equipment design for Bldg 6501.

Table 29. Bldg 6501 (double building) – details.

| Hangar | Volume (m³) | Factor (W/m³) | Length | Width | Average Height |
|---|---|---|---|---|---|
| Building characteristics | 25,000 + 25,000 | 11 | 50.0<br>50.0 | 39.4<br>39.4 | 12.7<br>12.7 |
| Building Condition | Medium quality insulation/doors insulated | | | | |
| Actual Heating System | Water-based air blowers (flow 80 °C /return 60 °C) | | | | |
| | Calculation | | | Remarks | |
| | by radiaTec | by Senergy GmbH | by Factor | | |
| Heating capacity (kW) | 580 | 591 | 550 | Only for radiant heating equipment | |
| Estimated Annual heat requirement (MWh) | | 925 | | | |
| Investment (rounded – accurate values see quotation radiaTec) | | | | | |
| (All values in €). | | | Remarks | | |
| Investment radiant heating equipment | 165,000 | | | | |
| Investment mounting and commissioning | 60,000 | | | | |
| Piping – new work | 16,000 | | Approximately 160 m/Price €100/m | | |
| Piping – demolition work | 12,000 | | Approximately 300 m/Price €40/m | | |
| Additional work | 15,000 | | Valves, sensors and control equipment. | | |
| Total Investment | 275,000 | | | | |

**Bldg 6502 –Illesheim**

Bldg 6500 – 6502 are constructed identically. The data in Table 30 describe Bldg 6502. Figure D7 (on p 216 of Appendix D to this report) shows the radiant heating equipment design for Bldg 6502.

Table 30. Bldg 6502 (double building) – details.

| Hangar | Volume (m³) | Factor (W/m³) | Length | Width | Average Height |
|---|---|---|---|---|---|
| Building characteristics | 25,000 + 25,000 | 11 | 50.0<br>50.0 | 39.4<br>39.4 | 12.7<br>12.7 |
| Building Condition | medium quality insulation/Doors insulated | | | | |
| Actual Heating System | Water-based air blowers (flow 80 °C /return 60 °C) | | | | |
| | Calculation | | | Remarks | |

| Hangar | Volume ($m^3$) | Factor ($W/m^3$) | Length | Width | Average Height |
|---|---|---|---|---|---|
| | by radiaTec | by Senergy GmbH | by Factor | | |
| Heating capacity (kW) | 580 | 591 | 550 | Only for radiant heating equipment | |
| Estimated Annual heat requirement (MWh) | | 925 | | | |
| Investment (rounded – accurate values see quotation radiaTec) | | | | | |
| (All values in €). | | | Remarks | | |
| Investment radiant heating equipment | 165,000 | | | | |
| Investment mounting and commissioning | 60,000 | | | | |
| Piping – new work | 16,000 | | Approximately 160 m/Price €100/m | | |
| Piping – demolition work | 12,000 | | Approximately 300 m/Price €40/m | | |
| Additional work | 15,000 | | Valves, sensors and control equipment. | | |
| Total Investment | 275,000 | | | | |

**Bldg 6633 –Illesheim**

Figures 61–63 show and the data in Table 31 describe Bldg 6633 (Motor Pool). Figure D8 (on p 217 of Appendix D to this report) shows the radiant heating equipment design for Bldg 6633.

Figure 61. Bldg 6633 – Motor Pool 1.

Figure 62. Bldg 6633 – Motor Pool 2.

Figure 63. Bldg 6633 – Air blower – doors (air blower connected to the door opening).

Table 31. Bldg 6633 (6 Motor Pools) – details.

| Hangar | Volume (m³) | Factor (W/m³) | Length | Width | Average Height |
|---|---|---|---|---|---|
| Building characteristics | 6 x 1,300 | 11 | 16.5 | 10.5 | 7.5 |
| Building Condition | medium quality insulation/Doors insulated | | | | |
| Actual Heating System | Water-based air blowers (flow 80 °C /return 60 °C) | | | | |
| | Calculation | | | Remarks | |
| | by radiaTec | by Senergy GmbH | by Factor | (Air Blowers at open doors will remain) | |
| Heating capacity (kW) | 120 | 91 | 85 | Only for radiant heating equipment | |
| Estimated Annual heat requirement (MWh) | | 315 | | | |
| Investment (rounded – accurate values see quotation radiaTec) | | | | | |
| (All values in €). | | | Remarks | | |
| Investment radiant heating equipment | 43,000 | | | | |
| Investment mounting and commissioning | 16,000 | | | | |
| Piping – new work | 12,000 | | Approximately 120 m/Price €100/m | | |
| Piping – demolition work | 12,000 | | Approximately 300 m/Price €40/m | | |
| Additional work | 15,000 | | Valves and control equipment. | | |
| Total Investment | | | | | |

### REN #10KS – REN #13KS – Photovoltaic systems at Ansbach

The buildings that were evaluated are marked on the site plan (Figure 64).

Bldgs 5508, 5801, 5802 are not appropriate to be for PV-Systems due to their orientation and static problems.

Bldgs 5805, 5806 and 5807 have acceptable orientations, but the roof characteristics cannot be used for PV-Systems based on the modules. In such cases, only building integrated roofing membrane technology is applicable. An acceptable economical efficiency can only be achieved by retrofitting the roofs.

Bldgs 9021, 5810 and 5819 show appropriate roof characteristics and acceptable orientations for PV-Systems based on modules. All other buildings at the installations are either not appropriate or they are in the shadow of trees or other irradiation obstacles. A very promising chance is to install a PV-System in the open space.

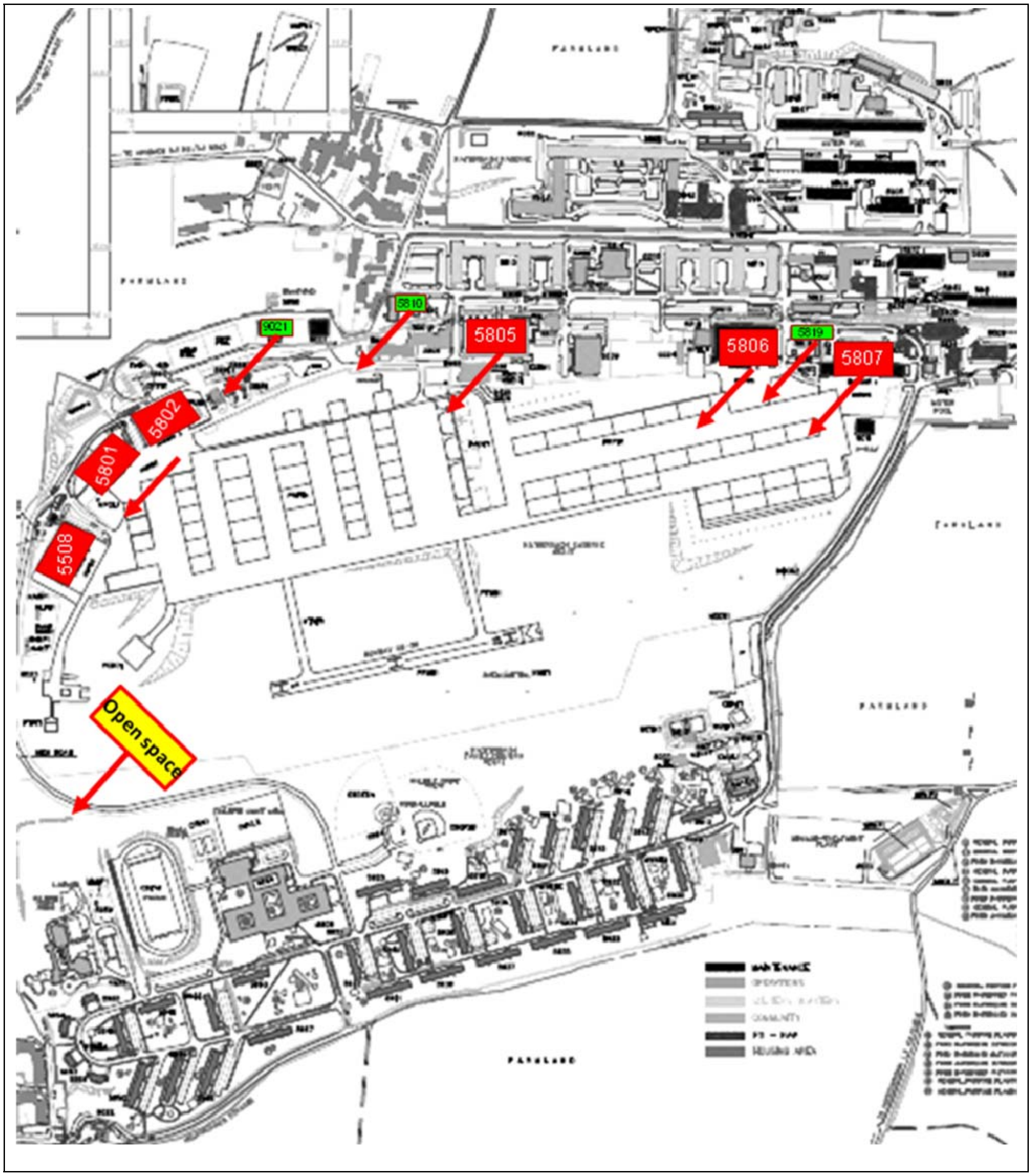


Figure 64. Site plan Ansbach with marked buildings and open space.

A freestanding, ground-placed PV-System was evaluated for this location. One major issue that must be resolved is that the reflection must not disturb the air traffic. This issue must be discussed and cleared with the air traffic management.

*REN #10KS PV System Bldg 9021 – Katterbach Barracks, Ansbach*

Figure 65 shows and the data in Table 32 describe (Warehouse) Bldg 9021 at Ansbach.

Figure 65. Bldg 9021/Warehouse – Ansbach.

Table 32. Bldg 9021 PV-System – Ansbach.

| Bldg | 9021 | Remarks |
|---|---|---|
| Location | Ansbach | |
| Footprint | 40 m x 20 m | |
| Roof Characteristic | Ridge Roof | |
| Inclination | 13 degrees | |
| Orientation | 130 degrees | |
| Area of PV-System | 356 $m^2$ | |
| No. of Modules | 540 | |
| Output | 43.47 kWp | |
| Roof Load/$m^2$ | 17.5 kg | |
| Estimated yearly results | | |
| Specific Annual Yield | 917 kW/kWp | |
| Grid Feed-in/yr | 39,853 kWh | First year/Degradation: 5% in 20 yrs |
| Total Revenue (20-yr period) | €354,408 | Installation End 2008 |
| Total Revenue (20.5-yr period) | €349,199 | Installation Mid 2009 |
| Investment Cost | €197,615 | Total Investment costs including installation |
| Investment Cost/kWp | €4,546 | |
| Break even time (without capital cost) | 9/10 yrs | Installation 2008/2009 |
| Liquidity cumulated (with capital cost) | €67,592/ €58,382 | Installation 2008/2009 |
| Real rate return | 34.2%/29.5% | Installation 2008/2009 |
| $CO_2$ Reduction cumulative | 257 t/263 t | Installation 2008/2009 |

*REN #11KS – PV System Bldg 5810 – Katterbach Barracks, Ansbach*

Figure 66 shows and the data in Table 33 describe existing conditions at Bldg 5810 (Fire brigade) at Ansbach.


Figure 66. Bldg 5810 (Fire Brigade) – Ansbach.

Table 33. Bldg 5810 (Fire Brigade) PV-System – Ansbach.

| Bldg | Fire Brigade 5810 | Remarks |
|---|---|---|
| Location | Ansbach | |
| Footprint | | |
| Roof Characteristic | Ridge Roof | |
| Inclination | 25 degrees | |
| Orientation | 30 degrees | |
| Area of PV-System | 490 m² | |
| No. of Modules | 680 | |
| Output | 54.74 kWp | |
| Roof Load/m² | 17.5 kg | |
| Estimated yearly results | | |
| Specific Annual Yield | 980 kW/kWp | |
| Grid Feed-in/yr | 53,650 kWh | First year/Degradation: 5% in 20 yrs |
| Total Revenue (20-yr period) | €479,096 | Installation End 2008 |
| Total Revenue (20,5-yr period) | €466,795 | Installation Mid 2009 |
| Investment Cost | €248,848 | Total Investment costs includ-ing installation |
| Investment Cost/kWp | €4,546 | |
| Break even time (without capital cost) | 10/11 yrs | Installation 2008/2009 |
| Liquidity cumulated (with capital cost) | €112,883/ €100,581 | Installation 2008/2009 |
| Real rate of return | 45.4%/40,4% | Installation 2008/2009 |
| $CO_2$ Reduction cumulative | 346 t/355 t | 20-yr period |

*REN #12KS – PV System Bldg 5819 – Katterbach Barracks, Ansbach*

Figure 67 shows and the data in Table 34 describe the existing conditions at Bldg 5819 (Office Building) at Ansbach.

Figure 67. Bldg 5819/Office – Ansbach.

Table 34. Bldg 5819 PV-System – Ansbach.

| Bldg | 5819 | Remarks |
|---|---|---|
| Location | Ansbach | |
| Footprint (Approximate) | 60 m x 14 m | |
| Roof Characteristic | Ridge Roof | |
| Inclination | 35 degrees | |
| Orientation | 150 degrees | |
| Area of PV-System | 480 $m^2$ | |
| No. of Modules | 680 | |
| Output | 53.13 kWp | |
| Roof Load/$m^2$ | 17.5 kg | |
| Estimated yearly results | | |
| Specific Annual Yield | 981 kW/kWp | |
| Grid Feed-in/yr | 52,123 kWh | First year/Degradation: 5% in 20 yrs |
| Total Revenue (20-yr period) | €465,841 | Installation End 2008 |
| Total Revenue (20,5-yr period) | €453,879 | Installation Mid 2009 |
| Investment Cost | €241,529 | Total Investment costs including installation |
| Investment Cost/kWp | €4,562 | |
| Break even time (without capital cost) | 10/11 yrs | Installation 2008/2009 |
| Liquidity cumulative (with capital cost) | €110,399/€98,436 | Installation 2008/2009 |
| Real rate of return | 45.7%/40.8% | Installation 2008/2009 |
| $CO_2$ Reduction cumulative | 336 t/345 t | 20-yr period |

*REN #13KS – PV System open space – Katterbach Barracks, Ansbach*

The layout of the free standing PV-Systems is identical in construction to that of the Open Space PV-System for Illesheim (Table 35).

Table 35. Open space PV-system – Ansbach.

| Bldg | Open Space | Remarks |
|---|---|---|
| Location | Ansbach | |
| Footprint | 154 m x 47 m | |
| Roof Characteristic | | |
| Inclination | 350 | |
| Orientation | 1800 | |
| Area of PV-System | 2.376 m² | |
| No. of Modules | 3,300 | |
| Output | 265.65 kWp | |
| Roof Load/m² | - | |
| Estimated yearly results | | |
| Specific Annual Yield | 967 kW/kWp | |
| Grid Feed-in/yr | 256,943 kWh | First year/Degradation: 5% in 20 yrs |
| Total Revenue (20-yr period) | €2,229,370 | Installation End 2008 |
| Total Revenue (20,5-yr period) | €2,172,119 | Installation Mid 2009 |
| Investment Cost | €1,268,027 | Total Investment costs including installation |
| Investment Cost/kWp | €4,773 | |
| Break even time (without capital cost) | 11/12 yrs | Installation 2008/2009 |
| Liquidity cumulated (with capital cost) | €363,297/ €306,045 | Installation 2008/2009 |
| Liquidity cumulated (with capital cost) | 28.7%/24.1% | Installation 2008/2009 |
| $CO_2$ Reduction cumulative | 1,657 t/1,699 t | 20-yr period |

## REN #14KS – REN #21KS Photovoltaic systems Storch Barracks, Illesheim

Figure 68 shows the site plan for Illesheim with marked buildings and open space.

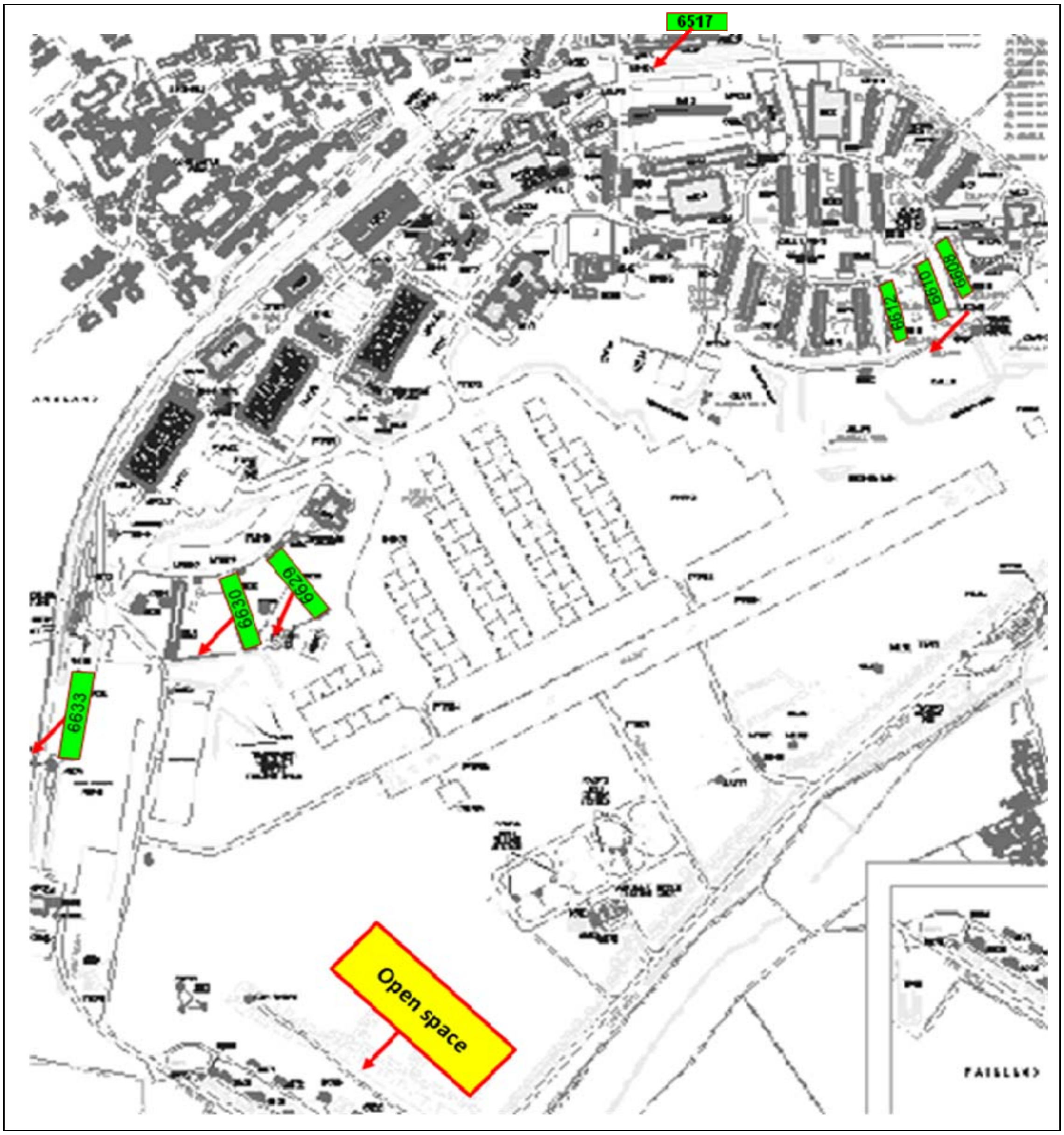


Figure 68. Site Plan Illesheim with marked buildings and open space.

Bldgs 6629, 6630, 6608, 6610, 6612 and 6517 show appropriate roof characteristics and acceptable orientations for PV-Systems based on modules.

The roof of Bldg 6633 is appropriate to install a free-standing PV-System on it.

The orientation, the inclination or the roof characteristic of all other buildings are not appropriate for installations of PV-Systems because of shadow or similar obstacles.

### REN #14KS and #15 – PV system Bldgs 6629 and 6630 – Storch Barracks, Illesheim

*Existing conditions*

Bldgs 6629 and 6630 are identical in construction (Figure 69, Table 36 and 37).


Figure 69. Bldgs 6629 and 6630 – Illesheim.

### *Costs and savings*

Table 36. Bldg 6629 PV-system – Illesheim.

| Bldg | 6629 | Remarks |
|---|---|---|
| Location | Illesheim | |
| Footprint | 93 m x 24 m | |
| Roof Characteristic | Ridge Roof | |
| Inclination | 19 degrees | |
| Orientation | 150 degrees | |
| Area of PV-System | 720 m² | |
| No. of Modules | 1,080 | |
| Output | 86,94 kWp | |
| Roof Load/m² | 17.5 kg | |
| Estimated yearly results | | |
| Specific Annual Yield | 965 kW/kWp | |
| Grid Feed-in/yr | 83,925 kWh | First year/Degradation: 5% in 20 yrs |
| Total Revenue (20-yr period) | €741,864 | Installation End 2008 |
| Total Revenue (20,5-yr period) | €722,836 | Installation Mid 2009 |
| Investment Cost | €395,229 | Total Investment costs including installation |
| Investment Cost/kWp | €4,546 | |
| Break even time (without capital cost) | 10/11 yrs | Installation 2008/2009 |
| Liquidity cumulated (with capital cost) | €160.231/ €141.203 | Installation 2008/2009 |
| Real rate of return | 40,5%/35,7% | Installation 2008/2009 |
| $CO_2$ Reduction cumulative | 541 t/555 t | 20-yr period |

Table 37. Bldg 6630 PV-system – Illesheim.

| Bldg | 6630 | Remarks |
|---|---|---|
| Location | Storch Barracks | |
| Footprint | 93 m x 24 m | |
| Roof Characteristic | Ridge Roof | |
| Inclination | 19 degrees | |
| Orientation | 150 degrees | |
| Area of PV-System | 720 m² | |
| No. of Modules | 1,080 | |
| Output | 86.94 kWp | |
| Roof Load/m² | 17.5 kg | |
| Estimated yearly results | | |

| Bldg | 6630 | Remarks |
| --- | --- | --- |
| Specific Annual Yield | 965 kW/kWp | |
| Grid Feed-in/yr | 83,925 kWh | First year/Degradation: 5% in 20 yrs |
| Total Revenue (20-yr period) | €741,864 | Installation End 2008 |
| Total Revenue (20.5-yr period) | €722,836 | Installation Mid 2009 |
| Investment Cost | €395,229 | Total Investment costs including installation |
| Investment Cost/kWp | €4,546 | |
| Break even time (without capital cost) | 10/11 yrs | Installation 2008/2009 |
| Liquidity cumulated (with capital cost) | €160,231/ €141,203 | Installation 2008/2009 |
| Real rate of return | 40.5%/35.7% | Installation 2008/2009 |
| $CO_2$ Reduction cumulative | 541 t/555 t | 20-yr period |

### REN #16KS – REN #18KS – PV system Bldgs 6608 and 661, and 6612 – Storch Barracks, Illesheim

The barracks Bldgs 6608, 6610 and 6612 are identical in construction (Figure 70, Tables 38-40).


Figure 70. Bldgs 6608, 6610, and 6612 – Illesheim.

Table 38. Bldg 6608 PV-system – Illesheim.

| Bldg | 6608 | Remarks |
|---|---|---|
| Location | Illesheim | |
| Footprint (Approximate) | 93 m x 12 m | |
| Roof Characteristic | Ridge Roof | |
| Inclination | 28.5 degrees | |
| Orientation | 164 degrees | |
| Area of PV-System | 540 m² | |
| No. of Modules | 780 | |
| Output | 62.79 kWp | |
| Roof Load/m² | 17.5 kg | |
| Estimated yearly results | | |
| Specific Annual Yield | 949 kW/kWp | |
| Grid Feed-in/yr | 59,533 kWh | First year/Degradation: 5% in 20 yrs |
| Total Revenue (20-yr period) | €529,942 | Installation End 2008 |
| Total Revenue (20,5-yr period) | €516,340 | Installation Mid 2009 |
| Investment Cost | €285,443 | Total Investment costs including installation |
| Investment Cost/kWp | €4,546 | |
| Break even time (without capital cost) | 10/11 yrs | Installation 2008/2009 |
| Liquidity cumulated (with capital cost) | €109,873/ €96,271 | Installation 2008/2008 |
| Real rate of return | €38.5%/33.7% | Installation 208/2009 |
| $CO_2$ Reduction cumulative | 384 t/394 t | 20-yr period |

Table 39. Bldg 6610 PV-system – Illesheim.

| Bldg | 6610 | Remarks |
|---|---|---|
| Location | Illesheim | |
| Footprint | 93 m x 12 m | |
| Roof Characteristic | Ridge Roof | |
| Inclination | 28.5 degrees | |
| Orientation | 158 degrees | |
| Area of PV-System | 540 m² | |
| No. of Modules | 780 | |
| Output | 62.79 kWp | |
| Roof Load/m² | 17.5 kg | |
| Estimated yearly results | | |

| Bldg | 6610 | Remarks |
|---|---|---|
| Specific Annual Yield | 943 kW/kWp | Approximately 10% higher than shown in Figure 8 |
| Grid Feed-in/yr | 59,222 kWh | First year/Degradation: 5% in 20 yrs |
| Total Revenue (20-yr period) | €526,994 | Installation End 2008 |
| Total Revenue (20,5-yr period) | €513,468 | Installation Mid 2009 |
| Investment Cost | €285,443 | Total investment costs including installation |
| Investment Cost/kWp | €4,546 | |
| Break even time (w/o capital cost) | 10/11 yrs | Installation 2008/2009 |
| Liquidity cumulated (with capital cost) | €106,926/ €93,399 | Installation 2008/2009 |
| Real rate of return | 37.5%/32.7% | Installation 2008/2009 |
| $CO_2$ Reduction cumulative | 382 t/391 t | 20-yr period |

Table 40. Bldg 6612 PV-system – Illesheim.

| Bldg | 6612 | Remarks |
|---|---|---|
| Location | Illesheim | |
| Footprint | 93 m x 12 m | |
| Roof Characteristic | Ridge Roof | |
| Inclination | 28.5 degrees | |
| Orientation | 155 degrees | |
| Area of PV-System | 540 $m^2$ | |
| No. of Modules | 780 | |
| Output | 62,79 kWp | |
| Roof Load/$m^2$ | 17.5 kg | |
| Estimated yearly results | | |
| Specific Annual Yield | 940 kW/kWp | Approximately 10% higher than shown in Figure 8 |
| Grid Feed-in/yr | 59,023 kWh | First year/Degradation: 5% in 20 yrs |
| Total Revenue (20-yr period) | €525,226 | Installation End 2008 |
| Total Revenue (20,5-yr period) | €511,745 | Installation Mid 2009 |
| Investment Cost | €285,443 | Total Investment costs including installation |
| Investment Cost/kWp | €4,546 | |
| Break even time (w/o capital cost) | 10/11 yrs | Installation 2008/2009 |
| Liquidity cumulated (with capital cost) | €105,157/ €91,676 | Installation 2008/2009 |
| Real rate of return | 36.8%/32.1% | Installation 2009 |
| $CO_2$ Reduction cumulative | 380 t/390 t | 20-yr period |

### REN #19KS – PV system Bldg 6517 – Storch Barracks, Illesheim

Figure 71 shows and the data in Table 41 describe Bldg 6517 (an office building) at Illesheim.

Figure 71. Office Bldg 6517 – Illesheim.

Table 41. Bldg 6517 PV-system – Illesheim.

| Bldg | 6517 | Remarks |
|---|---|---|
| Location | Illesheim | |
| Footprint (estimated) | 70 m x 16 m | |
| Roof Characteristic | Ridge Roof | |
| Inclination | 33 degrees | |
| Orientation | 180 degrees | |
| Area of PV-System | 560 $m^2$ | Reductions because of roof windows |
| No. of Modules | 780 | |
| Output | 62.79 kWp | |
| Roof Load/$m^2$ | 17.5 kg | |
| Estimated yearly results | | |
| Specific Annual Yield | 1,007 kW/kWp | |
| Grid Feed-in/yr | 63.262 kWh | First year/Degradation: 5% in 20 yrs |
| Total Revenue (20-yr period) | €562,952 | Installation End 2008 |
| Total Revenue (20,5-yr period) | €548,503 | Installation Mid 2009 |
| Investment Cost | €285,443 | Total Investment costs includ-ing installation |
| Investment Cost/kWp | €4,546 | |

| Bldg | 6517 | Remarks |
|---|---|---|
| Break even time (without capital cost) | 9/10 yrs | Installation 2008/2009 |
| Liquidity cumulated (with capital cost) | €142,884/ €128,435 | Installation 2008/2009 |
| Real rate of return | 50.1%/45.0% | Installation 2008/2009 |
| $CO_2$ Reduction cumulative | 408 t/418 t | 20-yr period |

### REN #20KS – Free-Standing PV System Bldg 6633 – Storch Barracks, Illesheim

Figure 72 shows Bldg 6633 (Motor Pool) at Illesheim.

Figure 72. Motor Pool Bldg 6633 – Illesheim.

Figure 73 shows a sketch of, and the data in Table 42 describe the proposed free-standing PV-System for Bldg 6633.

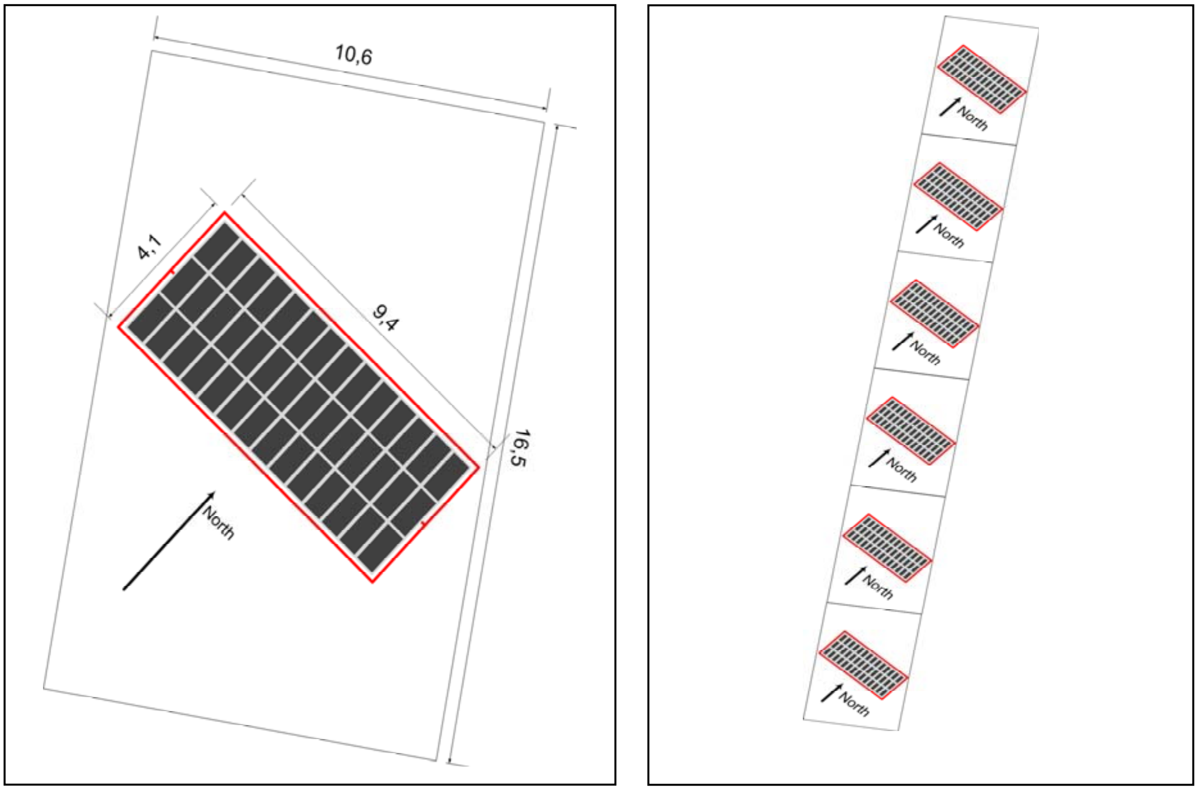


Figure 73. Sketch of free-standing PV-system for Bldg 6633.

Table 42. Bldg 6633 PV-system — Illesheim.

| Bldg | 6633/One Building | Remarks |
|---|---|---|
| Location | Illesheim | |
| Footprint | 16.5 m x 10.6 m | Six buildings |
| Roof Characteristic | Flat Roof | |
| Inclination | 30 degrees | |
| Orientation | 180 degrees | |
| Area of PV-System | 31 m² | Total: 186 m² |
| No. of Modules | 42 | Total: 252 |
| Output | 3.38 kWp | Total: 20,28 kWp |
| Roof Load/m² | 19.25 kg | 10% mark up because of carrier system |
| Estimated yearly results for all six PV-Systems | | |
| Specific Annual Yield | 990 kW/kWp | |
| Grid Feed-in/yr | 20,070 kWh | First year/Degradation: 5% in 20 yrs |
| Total Revenue (20-yr period) | €183,252 | Installation End 2008 Total |

| Bldg | 6633/One Building | Remarks |
|---|---|---|
| Total Revenue (20.5-yr period) | €178,536 | Installation Mid 2009 |
| Investment Cost | €96,804 | Total Investment costs including installation |
| Investment Cost/kWp | €4,773 | 5% mark up because of carrier system |
| Break even time (without capital cost) | 10/11 yrs | Installation 2008/2009 |
| Liquidity cumulated (with capital cost) | €40,794/ €36,078 | Installation 2008/2009 |
| Real rate of return | 42.1%/37.3% | Installation 2008/2009 |
| $CO_2$ Reduction cumulative | 130 t/133 t | 20-yr period |

### REN #21KS Open Space installation of PV System at Bldg 6633 (Storch Barracks), Illesheim

Figures 74 and 75 show and the data in Table 43 describe the positioning (distances/angle) of PV modules in an open space at Illesheim.

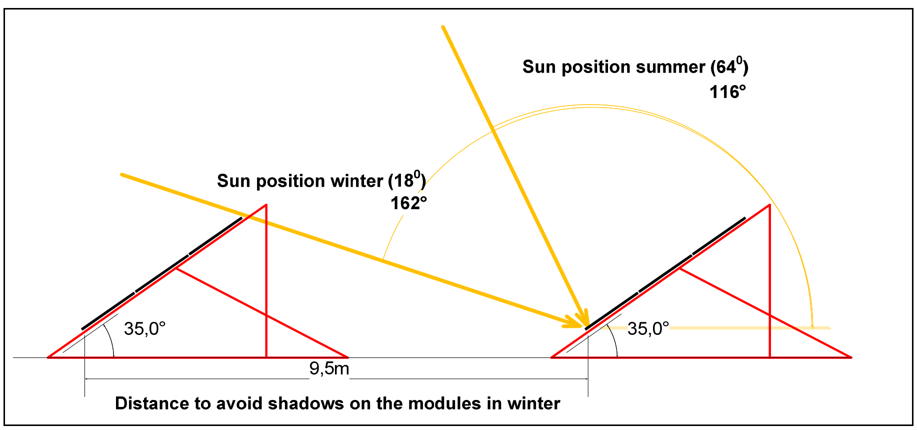


Figure 74. Positioning of modules in an open space – distances/angle.

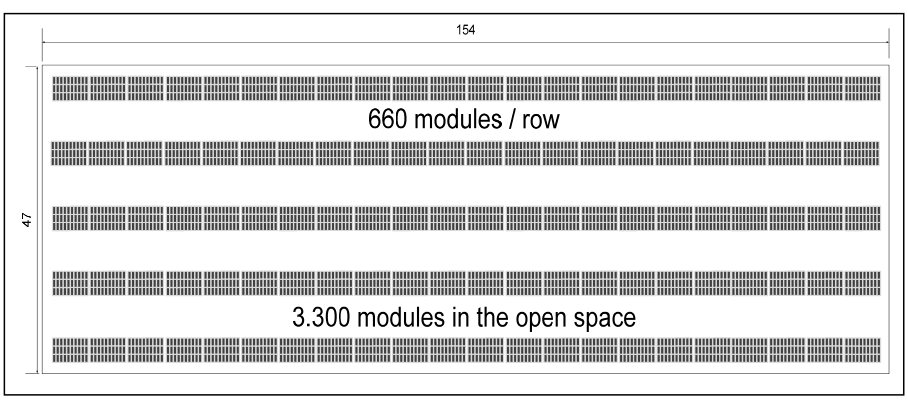


Figure 75. Positioning of modules in an open space – PV-system.

Table 43. Open space PV-system – Illesheim.

| Open Space | | Remarks |
|---|---|---|
| Location | Illesheim | |
| Footprint | 154 m x 47 m | |
| Roof Characteristic | — | |
| Inclination | 35 degrees | |
| Orientation | 180 degrees | |
| Area of PV-System | 2,376 $m^2$ | |
| No. of Modules | 3,300 | |
| Output | 265.65 kW | |
| Roof Load/$m^2$ | | |
| Estimated yearly results | | |
| Specific Annual Yield | 967 kW/kWp | |
| Grid Feed-in/yr | 256,943 kWh | First year/Degradation: 5% in 20 yrs |
| Total Revenue (20-yr period) | €2,229,370 | Installation End 2008 |
| Total Revenue (20,5-yr period) | €2,172,119 | Installation Mid 2009 |
| Investment Cost | €1,268,027 | Total Investment costs including installation |
| Investment Cost/kWp | €4,773 | 5% mark up because of carrier system |
| Break even time (without capital cost) | 11/12 yrs | Installation 2008/2009 |
| Liquidity cumulated (with capital cost) | €363,297/ €306,045 | Installation 2008/2009 |
| Real rate of return | 28.7%/24.1% | Installation 2008/2009 |
| $CO_2$ Reduction cumulative | 1,657 t/1,699 t | 20-yr period |

## Summary

Table 44 summarizes the ECMs for Katterbach and Storch Barracks.

Table 44. Summary of Katterbach and Storch Barracks ECMs.

| ECM # | ECM Description | Electrical Savings | | Thermal | | Maintenance (€/yr) | Total Savings: Electrical Use, Elec Demand, Thermal, and Maint (€/Yr) | Investment (€) | Simple Payback (yrs) |
|---|---|---|---|---|---|---|---|---|---|
| | | KWh/yr | €/yr | MMBtu/yr | €/Yr | | | | |
| RAD #1KS | Radiant Heating Katterbach Barracks Bldg 5801 | 0 | €0 | 519 | €12,768 | €0 | €12,768 | €103,000 | 8.1 |
| RAD #2KS | Radiant Heating Katterbach Barracks Bldg 5802 | 0 | €0 | 440 | €10,836 | €0 | €10,836 | €103,000 | 9.5 |
| RAD #3KS | Radiant Heating Katterbach Barracks Bldg 5806 | 0 | €0 | 478 | €11,760 | €0 | €11,760 | €190,000 | 16.2 |
| RAD #4KS | Radiant Heating Katterbach Barracks Bldg 5807 | 0 | €0 | 1270 | €31,248 | €0 | €31,248 | €129,000 | 4.1 |
| RAD #5KS | Radiant Heating Storch Barracks Bldg 6500 | 0 | €0 | 1461 | €35,952 | €0 | €35,952 | €268,000 | 7.5 |
| RAD #6KS | Radiant Heating Storch Barracks Bldg 6501 | 0 | €0 | 1239 | €30,492 | €0 | €30,492 | €268,000 | 8.8 |
| RAD #7KS | Radiant Heating Storch Barracks Bldg 6502 | 0 | €0 | 1464 | €36,036 | €0 | €36,036 | €268,000 | 7.4 |
| RAD #8KS | Radiant Heating Storch Barracks Bldg 6633 | 0 | €0 | 457 | €11,256 | €0 | €11,256 | €102,000 | 9.1 |
| REN #10KS | PV System Bldg 9021 – Katterbach Barracks, Ansbach | 39,853 | €17,720 | 0 | €0 | €0 | €17,720 | €197,615 | 11.2 |
| REN #11KS | PV System Bldg 5810 – Katterbach Barracks, Ansbach | 53,650 | €23,955 | 0 | €0 | €0 | €23,955 | €248,848 | 10.4 |
| REN #12KS | PV System Bldg 5819 – Katterbach Barracks, Ansbach | 52,123 | €23,292 | 0 | €0 | €0 | €23,292 | €241,529 | 10.4 |
| REN #13KS | PV System Open Space – Katterbach Barracks, Ansbach | 256,943 | €111,469 | 0 | €0 | €0 | €111,469 | €1,268,027 | 11.4 |
| REN #14KS | PV System Bldg 6629 – Storch Barracks, Illesheim | 83,925 | €37,093 | 0 | €0 | €0 | €37,093 | €395,229 | 10.7 |
| REN #15KS | PV System Bldg 6630 – Storch Barracks, Illesheim | 83,925 | €37,093 | 0 | €0 | €0 | €37,093 | €395,229 | 10.7 |
| REN #16KS | PV System Bldg 6608 – Storch Barracks, Illesheim | 59,533 | €26,497 | 0 | €0 | €0 | €26,497 | €285,443 | 10.8 |
| REN #17KS | PV System Bldg 6610 – Storch Barracks, Illesheim | 59,222 | €26,350 | 0 | €0 | €0 | €26,350 | €285,443 | 10.8 |
| REN #18KS | PV System Bldg 6612 – Storch Barracks, Illesheim | 59,023 | €26,261 | 0 | €0 | €0 | €26,261 | €285,443 | 10.9 |
| REN #19KS | PV System Bldg 6517 – Storch Barracks, Illesheim | 63,262 | €28,148 | 0 | €0 | €0 | €28,148 | €285,443 | 10.1 |
| REN #20KS | PV System Bldg 6633 – Storch Barracks, Illesheim | 20,070 | €9,163 | 0 | €0 | €0 | €9,163 | €96,804 | 10.6 |
| REN #21KS | PV System Open Space – Storch Barracks, Illesheim | 256,943 | €111,469 | 0 | €0 | €0 | €111,469 | €1,268,027 | 11.4 |
| *Totals* | | *1,088,472* | *€478,509* | *7328* | *€180,348* | *€0* | *€658,857* | *€6,684,080* | *10.1* |

## U.S. Army Depot – Germersheim

### BE #3US – Reduce door size Bldgs 7938 and 7941

*Existing conditions*

In two of the old Nike Storage Bldgs (7938 and 7941), there are three large doors (48 x 10-ft high) that were required for an earlier building function. Bldg 7938 has two of these doors and Bldg 7941 has one (Figure 76). These doors can be replaced with a smaller door that will still provide the access required. The large doors allow large amounts of cold air to enter in the winter when opened and have a poor insulating value when they are closed.

Figure 76. Large door at old Nike Bldg.

*Solution*

A smaller door that is 12 x 10 ft would be placed in the larger door opening. The space that is 36 x 10-ft high would be filled with an insulated removable panel to provide a greater resistance to heat loss. The proposed panels would be fiber glass or metal covered foam sections placed in the existing door opening. These panels would be screwed together providing a smooth surface. Provisions will be made to allow easy disassembly if the larger opening is ever needed. The estimated insulating value of this panel is 0.09 Btu/sq ft °F.

The door area should be inspected before these panels are installed and all cracks should be sealed or gasketed to provide a weather tight barrier. This will reduce the amount of cold air that infiltrates the building during the winter.

*Savings*

The insulating value of the current door panels is approximately 0.50 Btu/sq ft/°F. The estimated energy savings due to the reduced heat loss of these door panels is 14.6 $mWh_{th}$/yr providing an annual cost savings of €585. Opening the door allows cold air to enter the building in the winter. It is estimated that the door is open an average of four times a day for 5 minutes each time. When the door opens it is estimated cold air enters the building at a rate of 100 CFM/sq ft, or about 1 mph, a conservative estimate. Using an indoor temperature of 65 °F and an average outdoor temperature of 39 °F, the heat required to heat this outdoor air is 53.3 $mWh_{th}$/yr:

$$Q = (0.5 - 0.09) \text{ Btu/sq ft/°F} * 360 \text{ sq ft} * \text{three doors} * (65 - 39)\text{°F} * 4320 \text{ hrs/yr}/3413000 \text{ Btu/MWH} = 14.6 \text{ mWh}_{th}\text{/yr}$$

$$Q = 1.08 * 100 \text{ CFM} * 20\text{min}/60 \text{ min/hr} * 360 \text{ sq ft} * \text{three doors} * (65 - 39)\text{°F} * 180 \text{ days/yr}/3413000 \text{ Btu/MWH} = 53.3 \text{ mWh}_{th}\text{/yr}$$

The total energy cost savings is €2,500/yr.

$$\text{Cost Savings} = (14.6 + 53.3) \text{ mWh}_{th} * €36.8/\text{mWh}_{th} = €2{,}500\text{/yr}$$

*Investment*

The total door area to be filled is 1,080 sq ft. Using a cost of $10/sq ft, the total estimated installed cost is €10,800. The cost for three new 12 x 10 ft, doors is €19,500. Total cost of €30,300

*Payback*

The total energy savings is €2,500/yr resulting in a payback of the installation of these door panels of 12.1 yrs.

## CEP #5US – Connection of the "Big O" Buildings to the central heating system

This ECM analysis compares the alternatives of connecting the "Big O" buildings to the central heating system to that of supplying them with natural gas for heating. One issue with the first alternative concerns the whether ample capacity exists at the central plant, or if new capacity is required.

*Existing conditions – existing district heating system*

In Figure 77 a map of the existing district heating system is illustrated. The map shows the connected buildings of the district heating system, the "Big O" buildings, the plants and the pipes incl. pipe diameters.

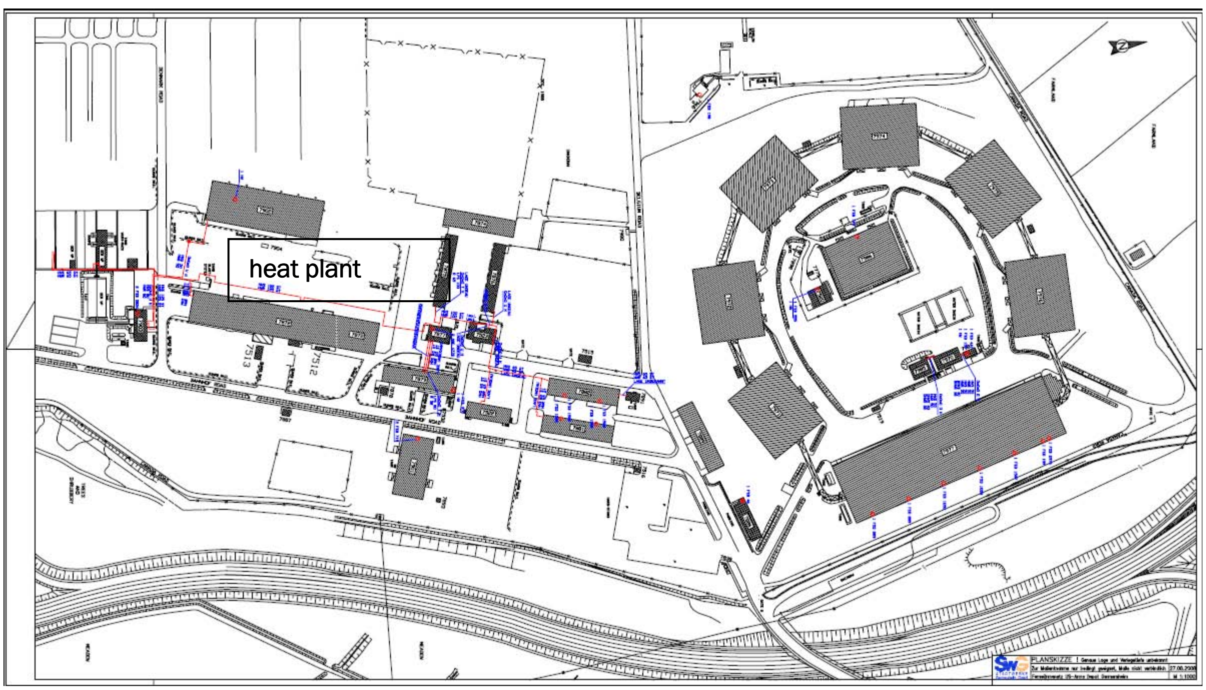


Figure 77. Map of the district heating system.

The supply and the return temperatures in the district heating system are presently 212/176 °F. Due to the new plant, the temperature level ought to be reduced to minimize the heat losses.

The nominal pressure level is 87 pounds per square inch (psi).

The plant consists of two hot water boilers with a maximum temperature of 248 °F and a capacity each with 7.5 MMBTU/h. The boilers have an efficiency factor of 0.92 (manufacturer's data). Currently the peak load is 7.17 MMBTU/h.

There is a possibility to expand the plant if the capacity is not sufficient. The hot water generation will be converted into solar technology in the course of modernization activities.

The new pumping set has a nominal flow rate of 220 gal per minute (gpm) and a nominal delivery height of 15 psi.

The fuel consumption in 2007 was 10,320 million BTU, which equates to $203,748. The fuel consumption will be reduced due to the new plant.

Activities for a reconstruction of the district heating system were started. The modernization activities will begin no sooner than 2009.

*Existing conditions – "Big O" buildings*

- The "Big O" buildings were recently completely. Their old oil-fired heating installations were replaced with new gas heating systems.
- There are no fuel economy data because the next heating period begins in October.
- The "Big O" buildings are used as warehouses.

*Conclusion*

Connection of the "Big O" buildings to the district heating system would not be economically justified since the buildings were recently equipped with new gas heating.

### HVAC #9US – Check temperature control and check OA damper functions for unit heaters — Bldg 7902

*Existing conditions/problems*

The Motor Pool, Bldg 7902 has a total of 14 unit heaters. The heat is supplied from the nearby central energy plant. Every unit heater has its own temperature sensor, presumably pre-set at 15 °C and they all also have an

OA intake with dampers to choose the ratio of OA entering the heater and thus the building. It is uncertain whether these dampers actually work and in such case how they are operated/controlled.

There are also old thermostats placed on the walls with various set points from 15 °C to 30 °C. Whether some of these thermostats still are operational or not was not possible to determine.

*Solution*

Check so that the new temperature sensors work and that they all have pre-set temperatures of 15 °C. If the functionality is available Set night and weekend set points to + 5 or + 10 °C. Remove all old thermostats.

Check all dampers; make sure that the heaters run with 100 percent Return air in winter. The infiltration through the 12 large rollup doors are sufficient to supply the quantities of fresh air that are needed.

Consider installing door switches as in Bldg 7971 and others in the “Big O,” which turn the heaters off whenever the nearest door is open.

*Savings*

Apparently, there is no separate meter for heat supplied to Bldg 7902. The annual heat used is estimated to be in the range of 2,000 MWh/yr. The annual savings by the proposed measures are around 5 percent of the annual heating energy use or 100 MWh annually. The value of the savings is 100 MWh * €36.8/MWh or €3,700.

*Investment*

The required investment, including door switches and some minor repairs to the heaters (dampers), will total €5,000.

*Payback*

The resulting payback will occur within 1.4 yrs.

### HVAC #9US – Optimize the use of compressed air and the sizing of the air compressors — Motor Pool Bldg 7902 Germersheim

*Existing conditions/problems*

Bldg 7902 in Germersheim has one large air compressor, a Kaeser CS90 with a 55 kW motor. This compressors is far too large for the current use of compressed air at the facilities. It was noted that the unit has been running quite a lot. A runtime meter indicated that out of a total of 11,052 operating hours, the compressor had only been loaded for 3,944 hrs. A screw compressor that runs unloaded uses approximately 50 percent of the power that is used when it is loaded.

*Solution*

1. Disconnect the presently used air compressor. Do not ever use them again. Buy new air compressors that are sized approximately 40 percent of the sizes of the present compressors.
2. Question the use of every single air-driven tool. There are electric alternatives available widely used in European manufacturing industry. Try to get rid of as many as possible of these tools since the use of compressed air is so energy inefficient.
3. Examine the possibilities to switch off the air compressor at nights and weekends when no one works. Are there pieces of equipment that need the system to be pressurized? If not, switch the compressors off when the buildings are not occupied.
4. Search the compressed air distribution for leaks at least every 4 months. The preferred method is using an ultra-sound leak detection device. Fix all identified leaks.
5. Consider to duct the heat from the compressor in through the walls into the motor pool area in winter to help heating the buildings. Make sure that the heat can be ducted to the outside in the summer when there is no need for heat.

*Savings*

The compressor uses approximately 55 kW when loaded and 27 kW when unloaded. Using these values and using the run time meter readings gives 65 percent of the daily hours in unloaded mode with no air being compressed. During the 250 working days of the year, un-productive energy use adds up to:

27 kW * 0.65 * 8 hrs/day * 250 days = 35,000 kWh

The different steps proposed above will lead to larger total savings than this since elimination of air-driven tools and a preventive leak detection program will also reduce the hours when the new compressors will run loaded; therefore the total annual energy savings are estimated to be in the range of 45,000 kWh/yr, worth €4,000.

If it is decided that also the heat from the compressor should be used the additional savings makes this an even more interesting ECM.

*Investment*

The required investment includes a new small compressor at Germersheim at a cost of approximately €15,000.

*Payback*

The resulting payback will occur within 3.7 yrs (not including heat recovery savings).

### LI #14US – Use occupancy sensors to turn off lights — Bldg 7951 and 7971

*Existing conditions*

At USAG Germersheim there are a number of warehouse buildings that are used throughout the day with variable occupancy. Visits of these buildings found overhead lights on with a minimum of personnel present. The result is many of the lights could be shut off and the resulting electrical energy saved.

An example is a warehouse whose Building number is 7951. During the site visit, it was observed that no one was in the building yet all the lights were on. The lighting uses fluorescent fixtures that have two, 4-ft T8 lamps. These are arranged with 11 fixtures/row. There are 10 rows of lights in the building. Some of these lights could be turned off to avoid wasting electrical energy.

*Solution*

In these spaces where use varies depending on the time and/or current activities, the lighting system can be best controlled by occupancy sensors. Occupancy sensors can be installed that automatically switch lights on when human movement is sensed. The lighting level will be maintained until a set period of time has elapsed with no human movement observed. A period of 5 to 10 minutes would be adequate to ensure the space is truly unoccupied.

Such lighting controls should be placed in all buildings at USAG Germersheim that have varied use patterns. These spaces should also have fluorescent lighting since the time for the bulb to light is almost instantaneous. Lighting systems using sodium vapor, mercury vapor or metal halide lights take several minutes for measurable light to be produced after energizing the bulb and thus are not conducive to occupancy sensor control.

*Savings*

The major area of savings would be the installation of occupancy sensors in storage areas that receive few visits a day. These sensors would turn the lights off during the low use periods. Table 45 lists a summary of the savings potential based of the spaces visited. The total estimated energy cost savings is €3,177/yr.

Table 45. Savings potential based of the spaces visited.

| Bldg | Space | Lights (W) | No. lights | Hrs per week | Percent Off | Hrs off Per Week | kW Saved Per Yr | Cost Saved | Sensor Cost | Payback Period |
|---|---|---|---|---|---|---|---|---|---|---|
| 7951 | Warehouse areas | 64 | 33 | 72 | 30% | 21.6 | 2372 | 212 | 2000 | 9.4 |
| 7951 | Warehouse areas | 64 | 22 | 72 | 40% | 28.8 | 2109 | 188 | 1500 | 8.0 |
| 7951 | Warehouse areas | 64 | 22 | 72 | 50% | 36 | 2636 | 235 | 1500 | 6.4 |
| 7971 | Warehouse rows | 64 | 297 | 72 | 40% | 28.8 | 28466 | 2,542 | 22,000 | 8.7 |

*Example calculation – Bldg 7951 first area*

Electrical savings = 33 fixtures * 0.064kW * 72 hr/wk * 30% * 52 wk/yr = 2,372 kWh/yr

Electrical cost savings = 2.372 kWh/yr * €0.0893/kWh= €212/yr

*Investment*

The cost to install infrared occupancy sensors and wiring to connect to the switches for the lights is estimated to be €2,000 for the first three rows of lights. The total estimate for the building is €5,000. The total cost for the buildings listed is shown in Table 45. The total investment for the buildings visited in this ECM is €27,000.

*Payback*

The payback for lighting controls in the subject buildings is 8.5 yrs. It is recommended that occupancy sensors be placed in all similar spaces that have fluorescent lighting.

### LI #15US – Dim lighting using daylighting controls — Bldg 7988

*Existing conditions*

In Warehouse Bldg 7988 there are several newly constructed spaces that have a high amount of light plus the natural light that enters through skylights (Figure 78). These areas are identified in Table 46. During the site visit, it was observed that all the ceiling lights were on in these areas when there was ample light entering through the skylights.

*Solution*

Install a photo cell lighting level sensor in these areas to measure the amount of daylighting being provided by the sky lights. If ample light is provided, then some or all of the lamps in the area can be turned off.

If these lamps are not turned off on bright sunny days excessive electrical energy use will continue.

*Savings*

The following analysis uses the Fork Truck Repair area in Bldg 7988 to exhibit the savings calculations. It is estimated these lights can be turned off for 6 hrs during a normal day or 25 percent of the time. The warehouse is in operation for 24 hrs/day 6 days/wk.

Figure 78. Fork truck repair area having adequate natural light through skylight with lights on.

Table 46. Calculated savings by turning lights off in the Fork Truck Repair area.

| Bldg | Space | Lights (W) | No. lights | Hrs per Week | Percent Off | Hrs off Per Week | kWh Saved Per Yr | Cost Saved | Sensor Cost | Payback Period |
|---|---|---|---|---|---|---|---|---|---|---|
| 7988 | Fork truck Repair | 64 | 32 | 144 | 25% | 36 | 3834 | 342 | 2400 | 7.0 |
| 7988 | Battery Charge Area | 64 | 40 | 144 | 25% | 36 | 4792 | 428 | 2400 | 5.6 |
| 7988 | Marshalling Area | 58 | 336 | 144 | 25% | 36 | 36482 | 3258 | 9600 | 2.9 |
| *Totals* | | | | | | | *45,108* | *4,028* | *14,400* | *3.6* |

Electrical Savings = 32 lamps * 64W * 144 Hrs/wk

* 52 wks/yr * 25% = 3,834 kWh/yr

Electrical Cost Savings = 3,834 kWh/yr * €0.0893/kWh = €342/yr

For all three buildings the savings are 45,108 kWh/yr or €4,028/yr.

*Investments*

The estimated cost to install two photocell light sensors and wiring to turn off the lights is €2,400 for Bldg 7988 fork truck area and €14,400 for all three areas.

*Payback*

The resulting payback for the three areas is 3.6 yrs

### LI #16US – Install skylight — Bldgs 7951 and 7988

*Existing conditions*

In warehouse Bldgs 7951 and 7988, no natural light enters the workspace (Figure 79). All the lights are kept on during the hours of occupancy and the spaces are still reasonably dark. These are single story buildings that could easily have skylights installed in the roof.

Figure 79. Warehouse area with no skylights.

*Solution*

Place two rows of skylights in Bldg 7951 and three rows in Bldg 7988. Install photo cell lighting level sensors in these areas to measure the amount of daylighting being provided by the sky lights. If ample light is provided, then some or all of the lamps in the area can be turned off.

If these lamps are not turned off on bright sunny days, excessive electrical energy use will continue.

*Savings*

Table 47 summarizes the savings potential of installing sky lights based of the spaces visited. Total estimated energy cost savings are €11,900/yr.

Table 47. Savings potential from installing sky lights based of the spaces visited.

| Bldg | Space | Lights (W) | No. lights | Hrs per week | Percent Off | Hrs off Per Week | kWh Saved Per Yr | Cost Saved | Sky light Cost | Payback Period |
|---|---|---|---|---|---|---|---|---|---|---|
| 7951 | warehouse area | 64 | 110 | 72 | 0.5 | 36 | 13179 | €1,177 | €39,540 | 33.6 |
| 7988 | warehouse area | 64 | 2000 | 72 | 0.25 | 18 | 119808 | €10,699 | €102,048 | 9.5 |

*Investments*

The estimated cost to install two rows of three 4 x 30-ft skylights in Bldg 7951 and three rows of four 4-ft x 40-in. sky lights in Bldg 7951 is €141,600. Individual building costs are shown in the Table 47.

*Payback*

The resulting payback is 33.6 yrs for Bldg 7951 and 9.5 yrs for Bldg 7988.

### LI #17US – New lighting system — Bldg 7902

*Existing conditions*

In Bldg 7902 the lighting system consists of 130 metal halide lights installed high in the building (Figure 80). This type of lamp provides 50 to 60 lumens/W of electrical input. These lamps could be replaced with more efficient lighting equipment.

Figure 80. Metal halide lighting of Bldg 7902.

*Solution*

Replace the metal halide light fixtures with a high performance fluorescent lighting system that uses six F32T8 lamps in each fixture. The total lumens provided will be approximately the same (2.6 million lumens before and 2.3 million lumens after). The lamps used in this system are more efficient and have a longer life.

If the metal halide lamps are not replaced, excessive electrical energy use will continue.

*Savings*

The estimated size of the metal halide lamps is 400W. This lamp will use approximately 455W of electricity including the ballast energy use. The replacement six lamp fluorescent lighting system will use 178W, yielding a savings of 277W:

Electrical savings = 0.277 kW * 130 lamps * 60 hrs./wk * 52 wks/yr
= 112,000 kWh/yr
Electrical Cost Savings = 112,000 kWh/yr * €0.0893/kWh = €10,000/yr

The maintenance of the metal halide system will have a cost for lamp replacement of approximately €106/lamp. These lamps have a life of 20,000 hrs, which amounts to 6.4 yrs with an annual use of 3,120 hrs. The resulting average maintenance/yr is €16.60/lamp or €2,200 for the building. The fluorescent lighting system has a cost of €70 to replace the six lamps in a fixture. These lamps have a life of 28,000 hrs or 9 yrs with an annual use of 3,120 hrs. The resulting average maintenance/yr is €7.80/lamp or €1,000 for the building. The annual maintenance cost savings is estimated to be €1,200.

The total cost savings of the high performance fluorescent lighting system is €11,200.

*Investments*

The estimated cost to install the high performance fluorescent lighting system is €62,400.

*Payback*

The resulting payback is 5.6 yrs.

### LI #18US – New lighting system — Bldgs 7987, 7988, and7989

*Existing conditions*

In Bldgs 7987, 7988, and 7989, there are old fluorescent lighting systems that need replacing (Figure 81). The lighting fixtures have lenses that have aged and limit the amount of light that can pass through them. There are approximately 2,000 lighting fixtures in these buildings that are located between storage aisles. Each row of lights consists of 75 percent 8-ft lamps and 25 percent 4-ft lamps. Each fixture has two lamps.

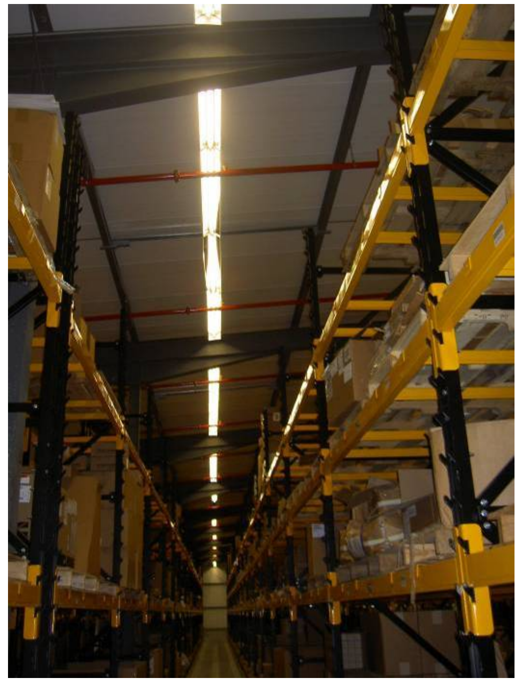

Figure 81. Old lighting system in warehouse buildings that need replacement.

*Solution*

Replace the old fluorescent lighting system with a new one that has high performance ballasts and F32T8 lamps in each fixture. The lighting system proposed will be more efficient and have a longer life.

If the old lighting system is not replaced, excessive electrical energy use will continue.

*Savings*

The estimated energy use of the new lighting system is 80 percent of the older system it would replace. The energy savings would then be 507 mWh/yr.

Existing system Electrical use = (1500 lights * 0.205 kW + 500 lights * 0.62 kW)
* 144 hrs/wk * 52 wk/yr = 2,535,000 kWh/yr

Electrical Energy savings = 2,535,000 kWh/yr * 20% = 507,000 kWh/yr

Electrical Cost Savings = 507,000 kWh/yr * €0.0893/kWh = €45,000/yr

The old fluorescent lighting system has a life of 20,000 hrs, which means the lamps will last 2.7 yrs. The new fluorescent lighting system lamp life will be 28,000 hrs, resulting in a life of 3.7 yrs. The cost to replace the old bulbs is €20 compared to a cost of €23 for the longer lasting bulbs. The resulting average current maintenance/yr is €7.40/light or €14,100 for the three buildings. The new fluorescent lighting system has an average annual cost of €6.22/light or €12.400 for the buildings. The annual maintenance cost savings is estimated to be €1,700.

The total cost savings of the high performance fluorescent lighting system is €46,700.

*Investments*

The estimated cost to install the high performance fluorescent lighting system is €448,000.

*Payback*

The resulting payback is 9.5 yrs.

### LI#19US – LI#24US – Lighting projects at Germersheim Warehouses (Big-O)

*Existing conditions*

The warehouses of Big-O in Germersheim (Figure 82) are operational approximately 20 hrs/day 365 days/yr.

The warehouse in the middle of the Big-O ring does not belong to the BIG-O.

In the seven warehouses of the Big-O the following lighting equipment is installed.

The “light on per day” estimation (Figure 82) is a result of the process observations during 3 days at different hours and based on the information from the users.

Figure 82. Warehouses Big-O – Germersheim.

Table 48. Light electricity consumption Big-O – existing situation.

| Bldg | 7971 | 7972 | 7973 | 7974 | 7975 | 7976 | 7977/1 | 7977/2 | 7977/3 | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| Number of installed tubes | 571 | 254 | 252 | 440 | 440 | 572 | 275 | 605 | 541 | 3,950 |
| Power per tube (W) | 58 | 58 | 58 | 58 | 58 | 58 | 58 | 58 | 58 | |
| Duration [h] "light on per day" | 6 | 20 | 6 | 6 | 6 | 6 | 20 | 20 | 20 | |
| Annual light electricity requirement [MWh] | 72 | 107 | 32 | 56 | 56 | 73 | 116 | 256 | 229 | 1,005 |
| Annual light electricity costs (€) | 5,802 | 8,603 | 2,560 | 4,471 | 4,471 | 5,812 | 9,314 | 20,492 | 18,324 | 79,853 |

The process analysis 2004 and the energy assessment 2008 indicates that the light is switched on in the warehouses much longer than "light on per day" value in Table 1 show.

The energy consumption might be higher in reality than calculated. Costs of €0.08/kWh were assumed.

*Process analysis – lighting/Bldg 7971*

Each yellow column is representing an aisle between the shelves. The blue sign 1 is representing "movement" of a forklift or a person in the aisle. The x is representing the required hysteresis "light on" of 5 minutes after the end of the movement in the aisle to ensure job safety and to minimize possible light switching.

The red frame is representing "light on" in the common areas (Table 49).

Table 49. Process observation Bldg 7971.

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1300 | | | | | | | | | | | | | |
| 1305 | | | | | | | | | | | | | |
| 1310 | | | | | | | | | | | | | |
| 1315 | | | | | | 1 | | | 1 | | | | 1 |
| 1320 | | | | | | X | 1 | | X | | | | X |
| 1325 | | | 1 | | | | X | | 1 | | | 1 | |
| 1330 | | | X | | 1 | | | | X | | | X | 1 |
| 1335 | | | | | X | | | | | | | | X |
| 1340 | | | | | | | | | | | | | |
| 1345 | | | | | | | | | | | | | |
| 1350 | | | | | | | | | | | | | |
| 1355 | | | | | | | | | | | | | 1 |
| 1400 | | | | | | | | | | | | | X |
| Total | | | 10 | | 10 | 10 | 10 | | 20 | | | 10 | 30 |

Observation Period 1
December 6th. 2004
13.00 – 14.00 hrs (1h)
No. of tubes total 572
No. of tubes/aisle 32 (approximately value)
No. of tubes/common areas 148
Light used 1 h x 572 x 58 W = 33,176 Wh
Light needed 0.58 h x 148 x 58 = 4,978 Wh
1.66 h x 32 x 58 = 3,081 Wh
Differences used – needed = 25,117 Wh
Minutes of "light on" in the aisle

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 900 | | | | | | | | | | | | | |
| 905 | | | | | | | | | | | | | |
| 910 | | | | | | | | | | | | | |
| 915 | | | | | | | | | | | | | |
| 920 | | | | | | | | | | | | | |
| 925 | | | | | | | | | | | | | |
| 930 | | | | | | | | | | | | | |
| 935 | | | | | | | | | | | | | |
| 940 | | | | | | | | | | | | | |
| 945 | | | | | | | | | | | | | |
| 950 | | | | | | | 1 | | | | | | |
| 955 | | | | | | | X | | | | | | 1 |
| 1000 | | | | | | | | | | | | | X |
| 1005 | | | | | | | | | | | | 1 | |
| 1010 | | | | 1 | 1 | 1 | | | | | | X | |
| 1015 | | | | 1 | X | 1 | | | | | | | |
| 1020 | | | | 1 | | X | | | | | | 1 | |
| 1025 | | | | X | | | | | | | | X | |
| 1030 | | | | | | | | | | | | | |
| 1035 | | | | | | | | | | | | | |
| 1040 | | | | | | | 1 | | | | | | |
| 1045 | | | | | | | X | | | | | | |
| 1050 | | | | | | | 1 | | | | | | |
| 1055 | | | | | | | X | | | | | | |
| 1100 | | | | | | | | | | | | | |

Observation Period 2
December 7th. 2004
0900 hrs – 1400 hrs (5 h)
No. of tubes total 572
No. of tubes/aisle 32 (approximately value)
No. of tubes/common areas 148
Light used 5 h x 572 x 58 W = 165,880 Wh
Light needed 1.66 h x 148 x 58 = 14,249 Wh
2.33 h x 32 x 58 = 4,324 Wh
Difference used – needed = 147,307 Wh
Random Sampling
During all on-site investigations a random walk around through all buildings at different times showed a permanent illumination of the entire Bldg 7971.
Process information for Bldg 7971 from Defense Distribution Depot Europe (DDDE)
Process time max. 6.0 h/day
Peak time 0.0 hrs
Observed illumination time of the building exceeds the process time.
Estimated power used/yr
72.655 kWh
Estimation power needed/yr
Power needed in the observation period
4.438.66 kWh/h
Uncertainty mark up = 30%
Calculation base power needed 5,770 kWh/h
Process time/day = 6 hrs

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1105 | | | | | | | | | | | | | |
| 1110 | | | | | | | | | | | | | |
| 1115 | | | | | | | | | | | | | |
| 1120 | | | | | | | | | | | | | |
| 1125 | | | | | | | | | | | | | |
| 1130 | | | | | | | | | | | | | |
| 1135 | | | | | | | | | | | | | |
| 1140 | | | | | | | | | | | | | |
| 1145 | | | | | | | | | | | | | |
| 1150 | | | | | | | | | | | | | |
| 1155 | | | | | | | | | | | | | |
| 1200 | | | | | | | | | | | | | |
| 1205 | | | | | | | | | | | | | |
| 1210 | | | | | | | | | | | | | |
| 1215 | | | | | | | | | | | | | |
| 1220 | | | | | | | | | | | | | |
| 1225 | | | | | | | | | | | | | |
| 1230 | | | | | | | | | | | | | |
| 1235 | | | | | | | | | | | | | |
| 1240 | | | | | 1 | | | | | | | | |
| 1245 | | | | | X | | 1 | | | | | | |
| 1250 | | | | | | | 1 | | | | | | |
| 1255 | | | | | | | 1 | | | | | | |
| 1300 | | | | | | | 1 | | | | | | |
| 1305 | | | | | | | X | | | | | | |
| 1310 | | | | | | | | | | | | | |
| 1315 | | | | | | | | | | | | | |
| 1320 | | | | | | | | | | | | | |
| 1325 | | | | | | | | | | | | | |
| 1330 | | | | | | | | | | | | | |
| 1335 | | | | | | | | | | | | | |
| 1340 | | | | | | | | | | | | | |
| 1345 | | | | | | | | | | | | | |
| 1350 | | | | | | | | | | | | | |
| 1355 | | | | | | | | | | | | | |
| 1400 | | | | | | | | | | | | | |
| Total | | | | 20 | 20 | 15 | 55 | | | | | 20 | 10 |

Process time/yr = 2,190 hrs
Power needed/yr 12,636 kWh
Power saving potential/yr
Approximately 60.019 kWh
(Probably higher because of workers behavior)
Annual Electricity costs used
Approximately €5,800
Annual Electricity costs needed
Approx €1,010
Saving Potential/yr
Approx €4,800

Minutes of “light on” in the aisle

*Process analysis – lighting/Bldg 7972 and 7977/1*

In Bldg 7972 and 7977/1 the delivery/shipment process is performed. There are all kinds of movements (persons, forklifts) possible. The directions of the movement are not predictable because of the variations in the delivery/shipment process itself and the usage of the buildings' areas. The area of the buildings is not divided by shelves or similar barriers. Therefore, a permanent switching of the light will affect the labor quality and probably the job safety in a negative way.

The process information given by DDDE indicates a process time of approximately 20 hrs. Due to the results of the process analysis, there is no energy saving potential seen in these two buildings.

*Process analysis – lighting/Bldg 7973 – 7976*

After a few hours of observing these building the process analysis in these buildings was aborted. There were no or very few movements observed. Taking the process information from DDDE into account it seems to be obvious that in the Bldgs 7973 – 7975 a minor energy saving potential is achievable.

There is a certain contradiction between the results of the process analysis. The process information from DDDE and the impressions got during the on-site checks 2004 and the assessment 2008. Very often the buildings were completely illuminated and no activities in the buildings could be recognized.

Therefore there are some doubts of whether the process time is identical with the illumination time. Certainly the behavior of the employees in terms of using light is comparable with the results of the observation results of Bldg 7971. For this reason, these buildings are included in the lighting calculations and concept with a saving potential set to be equal to the results of Bldg 7971.

*Process analysis – lighting/Bldg 7977-2*

Each yellow column is representing an aisle between the shelves. The blue sign 1 is representing "movement" of a forklift or a person in the aisle. The x is representing the required hysteresis "light on" of 5 minutes after the end of the movement in the aisle to ensure job safety and to minimize possible light switching. The red frame represents "light on" in the common areas (Table 50).

Table 50. Process observation Bldg 7977/2.

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 900 | | | | | | | | | | | | | |
| 905 | | | | | | | | | | | | | |
| 910 | | | | | | | | | | | | | |
| 915 | | | | | | | | | | | | | |
| 920 | | 1 | | | | | | | | 1 | | | |
| 925 | | 1 | 1 | | | | | | | 1 | | | |
| 930 | | X | 1 | | | | | | | X | 1 | | |
| 935 | | | X | | | | | | | | 1 | | |
| 940 | | | | | | | | | | | 1 | | |
| 945 | | | 1 | | | | | | | | X | | |
| 950 | | | 1 | | | | | | | | | | |
| 955 | 1 | 1 | X | | | | | | | 1 | | | |
| 1000 | 1 | 1 | | | | | | | | X | | | |
| 1005 | X | X | | | | | 1 | | | | | 1 | |
| 1010 | | 1 | | | | | 1 | 1 | | 1 | | 1 | |
| 1015 | | X | 1 | | | | 1 | 1 | | X | | X | |
| 1020 | | | X | 1 | | 1 | X | X | | | | | |
| 1025 | | | | 1 | 1 | 1 | | 1 | | | | | |
| 1030 | | | 1 | 1 | X | X | 1 | 1 | | | | | |
| 1035 | | | 1 | X | | | 1 | X | 1 | | | 1 | |
| 1040 | | 1 | X | 1 | | | 1 | 1 | X | 1 | | X | |
| 1045 | | X | | X | | | 1 | X | | 1 | | | |
| 1050 | | | | | | | X | | | 1 | | | |
| 1055 | | | | | 1 | | | | | 1 | | | |
| 1100 | | | 1 | | 1 | 1 | | | 1 | X | | | |
| 1105 | | 1 | 1 | | 1 | X | 1 | 1 | X | | | | |
| 1110 | | 1 | X | | 1 | | X | 1 | | | | | |
| 1115 | | X | | | 1 | | | 1 | | | | | |
| 1120 | | | | | X | | 1 | X | | | | | 1 |
| 1125 | | | | | | 1 | 1 | | | | | | X |
| 1130 | | | | | | X | X | | | | | | |
| 1135 | | | | | | 1 | | | | | | | |
| 1140 | | | | | | X | | | | | | | |
| 1145 | | | | | | 1 | | | | | | | |
| 1150 | | | | | | X | | | | | | | |
| 1155 | | | | | | | | | | | | | |
| 1200 | | | | | | | | | | | | | |
| 1205 | | | | | 1 | | | | | | | | |
| 1210 | | | | | X | | | | | | | | |
| 1215 | | | | | | | | | | | | | |

Observation Period 1

December 7th. 2004

0900 hrs – 1300 hrs (4 h)

No. of tubes total 605

No. of tubes/aisle 36 (approximately value)

No. of tubes/common areas 101

Light used 4 h x 605 x 58 W = 140,360 Wh

Light needed 3.25 h x 101 x 58 = 19,038 Wh

9.66 h x 36 x 58 = 20,170 Wh

Difference used – needed = -101,152 Wh

The energy saving potential might be higher. The common areas contain two more aisles without shelves, which were not observed. In the new lighting concept these two aisles are included.

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1220 | | | | | | | | | | | | | |
| 1225 | | | | | | 1 | | | | | | | |
| 1230 | | | | | | X | | | | | | | |
| 1235 | | | | | 1 | | | | | | | | |
| 1240 | | | | | X | | | | | | | | |
| 1245 | | | | | | | | 1 | | | | | |
| 1250 | | | | | | | | X | | | | | |
| 1255 | | | | | | | | | | | | | |
| 1300 | | | | | | | | | | | | | |
| | 15 | 65 | 70 | 30 | 60 | 65 | 70 | 70 | 20 | 60 | 20 | 25 | 10 |

Minutes of “light on” in the aisle

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 600 | | | | | | | | | | | | | |
| 605 | | | | | | | | | | | | | |
| 610 | | | | | | | | | | | | | |
| 615 | | | | | | | | | | | | | |
| 620 | | | | | | | | | | | | | |
| 625 | | | | | | | 1 | | | | | | |
| 630 | | | | | | | 1 | | | | | | |
| 635 | | | | | | | 1 | | | | | | |
| 640 | | | | | | | 1 | | | | | | |
| 645 | | | | | | | 1 | | | | | | |
| 650 | | | | | | | 1 | | | | | | |
| 655 | | | | | | | 1 | | | | | | |
| 700 | | | | | | | 1 | | | | | | |
| 705 | | | | | | | 1 | | | | | | |
| 710 | | | | | | | X | | | | | | |
| 715 | | | | | | | 1 | | | | | | |
| 720 | | | | | | | 1 | | | | | | |
| 725 | | | | | | | 1 | | | | | | |
| 730 | | | | | | | 1 | | | | | | |
| 735 | | | | | | | 1 | | | | | | |
| 740 | | | | | | | 1 | | 1 | | | | |
| 745 | 1 | 1 | | | | | 1 | | 1 | | 1 | | |
| 750 | 1 | 1 | | | | | 1 | | 1 | | 1 | | |
| 755 | 1 | 1 | | | | | 1 | | 1 | | 1 | | |
| 800 | X | X | | | | | X | | X | | X | | |
| | 20 | 20 | | | | | 100 | | 25 | | 20 | | |

Observation Period 2
December 8th. 2004
06.00 am – 08.00 am (2 h)
No. of tubes total 605
No. of tubes/aisle 36 (approximately value)
No. of tubes/common areas 101
Light used 2 h x 605 x 58 W = 70,180 Wh
Light needed 1.66 h x 101 x 58 = 9,724 Wh
3.08 h x 36 x 58 = 6,431 Wh
Differences used – needed = 54,024 Wh
The energy saving potential might be higher. The common area contains two more aisles without shelves, which were not observed. In the new lighting concept these two aisles are included.

Minutes of “light on” in the aisle

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1000 | | | | | | | | | | | | | |
| 1005 | | | | | | | | | | | | | |
| 1010 | | | | | | | | | | | | | |

Observation Period 3
December 8th. 2004
10.00 am – 12.00 am (2 h)

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1015 | | | | | | | | | | | | | |
| 1020 | 1 | 1 | 1 | | | | | 1 | | | | | |
| 1025 | 1 | 1 | 1 | | 1 | | | 1 | | | | | |
| 1030 | 1 | 1 | 1 | | X | | | 1 | | | | | |
| 1035 | 1 | 1 | 1 | 1 | | | 1 | 1 | | | | | |
| 1040 | 1 | 1 | 1 | 1 | | | 1 | X | | | | | |
| 1045 | 1 | 1 | 1 | 1 | | | 1 | 1 | | | | | |
| 1050 | X | X | 1 | 1 | | 1 | 1 | X | | | | | |
| 1055 | 1 | | X | 1 | | 1 | X | | | | | | |
| 1100 | 1 | | | 1 | | 1 | | | | | | | |
| 1105 | 1 | | | 1 | 1 | X | | | | | | | |
| 1110 | 1 | | 1 | 1 | 1 | | | | | | | | |
| 1115 | 1 | | X | 1 | 1 | | | 1 | | | | | |
| 1120 | 1 | | | X | 1 | | | 1 | 1 | | | | |
| 1125 | 1 | | 1 | 1 | 1 | | 1 | 1 | X | 1 | | | |
| 1130 | 1 | | 1 | 1 | 1 | | 1 | 1 | | 1 | | | |
| 1135 | 1 | | 1 | X | 1 | 1 | X | 1 | | X | | | |
| 1140 | 1 | | 1 | | X | 1 | | 1 | 1 | | | | |
| 1145 | X | | X | | | X | | 1 | 1 | | | | |
| 1150 | | | | | | | | 1 | 1 | | | | |
| 1155 | | | | | | | | 1 | 1 | 1 | | | |
| 1200 | | | | | | | | 1 | 1 | 1 | | | |
| 1205 | | | | | | | | X | X | X | | | |
| | 90 | 35 | 75 | 65 | 50 | 35 | 40 | 90 | 40 | 30 | | | |

Minutes of “light on” in the aisle

No. of tubes total 605
No. of tubes/aisle 36 (approximately value)
No. of tubes/common areas 172
Light used 2 h x 605 x 58 W = 70,180 Wh
Light needed 1.66 h x 101 x 58 = 9,724 Wh
9.16 h x 36 x 58 = 19,126 Wh
Difference used – needed = 41,329 Wh
The energy saving potential might be higher. The common areas contain two more aisle without shelves, which were not observed. In the new lighting concept these two aisles are included.
Process information for Bldg 7971 from DDDE
Process time 20 h/day
Peak time 8.0 hrs/day
Process time/yr = 7.300 h

*Conclusion Bldg 7977/2*

The results of the process analysis of Bldg 7977/2 is certainly not representative referring to a correct probability calculus, but the assumption is allowed that the building is currently illuminated during the whole year for at least 20 hrs/day:

Estimated light used/yr 256,157 kWh

Estimation light needed/yr 101,500 kWh

Power needed in the observation period 10,740 kWh/hr

uncertainty mark up = 30%

Annual Electricity costs used approximately €20,492

Annual Electricity costs needed approx €8,120

Saving potential/yr approx €12,272

*Process analysis – lighting/Bldg 7977-3*

Each yellow column is representing an aisle between the shelves (Table 51). The blue sign 1 is representing “movement” of a forklift or a person in the aisle. The x is representing the required hysteresis “light on” of 5 minutes after the end of the movement in the aisle to ensure job safety and to minimize possible light switching. The red frame represents “light on” in the common areas.

Table 51. Process observation Bldg 7977/3.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 600 | | | | | | | | | | | Observation period 1 |
| 605 | | | | | | 1 | | | | | December 8th. 2004 |
| 610 | | | | | | 1 | | | | | 06.00 am – 8.00 am (2 h) |
| 615 | | | | | | 1 | | | | | No. of tubes total 541 |
| 620 | | | | | | 1 | | | | | No. of tubes/aisle 40 (approximately value) |
| 625 | | | | | | X | | | | | No. of tubes/common areas 101 |
| 630 | | | | | | | | | | | Light used 2 h x 541 x 58 W = 62,756 Wh |
| 635 | | | | | | | | | | | Light needed 1.08 h x 101 x 58 = 6,326 Wh |
| 640 | | | | | | | | | | | 1.16 h x 40 x 58 = 2,691 Wh |
| 645 | | 1 | | | | | | | | | Difference used – needed = 53,739 Wh |
| 650 | | 1 | | | | | | | | | The energy saving potential might be higher. |
| 655 | | X | | | | | | | | 1 | The common areas contain two more aisle |
| 700 | | | | | | | | | | X | without shelves, which were not observed. In |
| 705 | | | | | 1 | | | | | | the new lighting concept these two aisles are |
| 710 | | | | | X | | | | | | included. |
| 715 | | | | | | | | | | | Process information for Bldg 7977 from DDDE |
| 720 | | | | | | | | | | | Process time 20 h/day – Peak time 8.0 hrs/day |
| 725 | | | | | | | | | | | Process time/yr = 7,300 h |
| 730 | | | | | | | | | | | |
| 735 | | | | | | | | | | | |
| 740 | | | | | | | | | | | |
| 745 | | | | | | | | | | | |
| 750 | | | | | | | | | | | |
| 755 | | | | | | | | | | | |
| 800 | | | | | | | | | | | |
| | 15 | | | | 10 | 25 | | | | 10 | Minutes of “light on” in the aisle |

*Conclusion Bldg 7977/3*

The results of the process analysis of Bldg 7977/3 is certainly not representative referring to a correct probability calculus, but the assumption is allowed that the building is currently illuminated during the whole year for at least 20 hrs/day:

Estimated light used/yr 229,059 kWh

Estimation light needed/yr 85,410 kWh

Power needed in the observation period 10,740 kWh/hr uncertainty mark up = 30%

Annual Electricity costs used approximately €18,324

Annual Electricity costs needed approx €6,832

Saving potential/yr approx €11,492

*Summary of energy saving potential*

The results of the process analysis and the above-mentioned estimations lead to the electricity saving potentials. The estimated electricity saving potentials listed in Table 52 are lower than those calculated above. The reason is the spotlight characteristic of the process observation. To come to highly reliable estimates, the calculated results of the process analysis are decreased again.

Table 52. Light electricity consumption Big-O with saving potential.

| Bldg | 7971 | 7972 | 7973 | 7974 | 7975 | 7976 | 7977/1 | 7977/2 | 7977/3 | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| Number of Installed Tubes | 571 | 254 | 252 | 440 | 440 | 572 | 275 | 605 | 541 | 3950 |
| Power per Tube (W) | 58 | 58 | 58 | 58 | 58 | 58 | 58 | 58 | 58 | |
| Duration [H] Light “on” per Day | 6 | 20 | 6 | 6 | 6 | 6 | 20 | 20 | 20 | |
| Annual Light Electricity Requirement [kWh] | 72 | 107 | 32 | 56 | 56 | 73 | 116 | 252 | 229 | 1.005 |
| Electricity Costs/kWh | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | |
| Annual Light Electricity Costs | 5,802 | 8,603 | 2,560 | 4,471 | 4,471 | 5,812 | 9,314 | 20,492 | 18,324 | 80,395 |
| Electricity Saving Potential | 3,500 | 0 | 1,500 | 2,700 | 2,700 | 3,500 | 0 | 12,000 | 11,000 | 36,900 |

The saving potential based on the process analysis and the information received from the operators of the buildings leads to a value of €36,900/yr. This is 46 percent of the actual electricity costs. These potential savings should be invested in light control equipment as designed in the following Chapter.

*Solution: Lighting concept for Big-O*

The frame for the new lighting concept is given by the following criteria:

- Operational safety/job safety
- Acceptable labor comfort for the employees
- Flexibility in rearranging of the warehouses
- Acceptable industrial safety/redundancy
- Return of investment (5 yrs)
- Compliance with workplace regulations (ArbStätt 5.007.3).

The major guideline of the design of the new lighting concept is:

- Only use light – if light is needed
- The movements in the common areas and in the aisles will be controlled with motion detectors.
- To ensure job safety and labor comfort a hysteresis in the switching circuits will be implemented, to avoid switching off the light while persons are working at one place without moving.
- The light in the common areas of a building will only will be switched off, if no movements in the entire building is detected for more then one hysteresis period.
- The programmable controller, which is controlling the movement via the motion detectors and switching the light accordingly, has to contain a programmed logic to adjust the hysteresis period if necessary. For instance, if the light is switched off more than 5 times shortly after the end of the hysteresis period, the programmed logic has to lengthen the hysteresis period.
- In addition to the control functions of the programmable controller a memory should be implemented. The memory is to monitor the movements (light-on/light-off periods) in the common areas and in the aisles. With this information, reported regularly, the facility management of the buildings might be able to adjust the process in the buildings.

*Light control equipment*

The following movement example shows a possible scenario for the Bldgs 7971 – 7976:

- The entrance to the building will take place through the doors 1 or 2.
- The light in the common area C1 will be switched on.
- Moving into an aisle the light in the aisle (Cx) will be switched on.
- Moving to another aisle via the common area C2 the light in this common area will be switched on and after it, the light in the next aisle (Cy) will be switched on.
- The light in the first aisle (Cx) will be switched off after the hysteresis period, if no further movement will be detected.
- Leaving the aisle (Cy) the light in the aisle will be switched off after one hysteresis period.
- All lights in the common areas will be switched off after 5 minutes without any movement in the building.

All motion detectors of an aisle are connected to the switching unit with a disjunction. All motion detectors of a common area are connected to the switching unit with a disjunction. In addition to that all switching signals of the aisles are connected to the switching unit of the common areas with a disjunction as well (Figure 83).

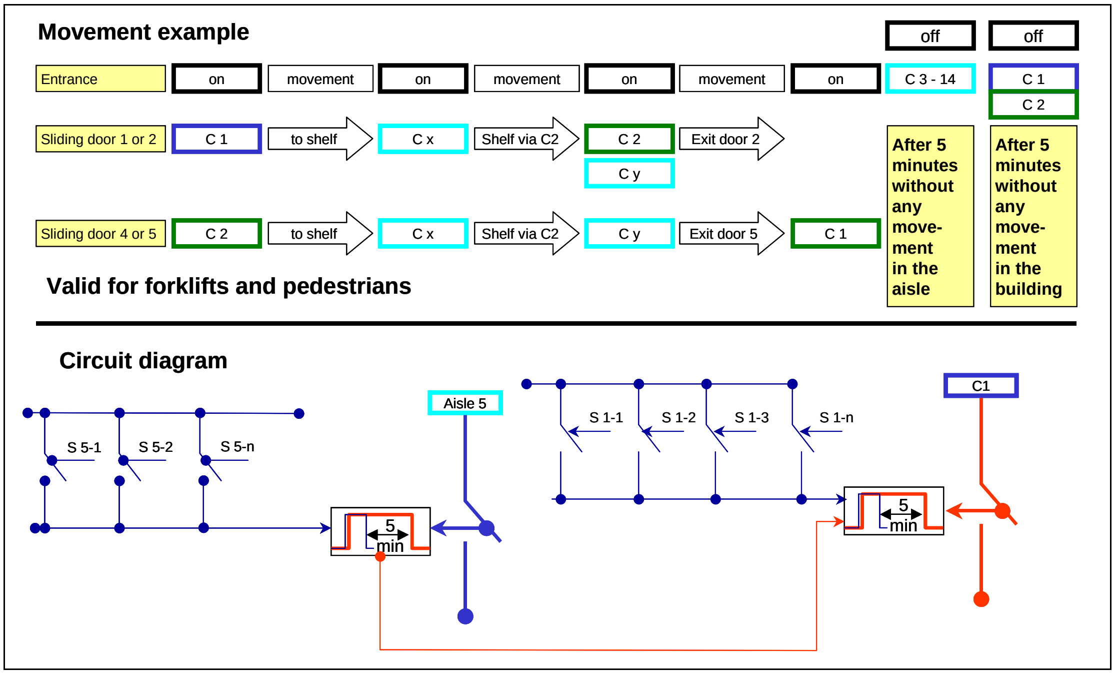


Figure 83. Example process and circuit diagram (Bldgs 7971 – 7976).

*Investment and Payback*

The amortization time for this light project is about 2.6 yrs (Table 53). These light-electricity saving measures are applicable to many other ware-houses in Germersheim and other Garrisons.

Table 53. Economic efficiency calculation lighting project Big-O.

| Bldg/Position | 7971 | 7973 | 7974 | 7975 | 7976 | 7977-2 | 7977-3 | Total Position |
|---|---|---|---|---|---|---|---|---|
| Rearrangement of Tube-Connections (h) | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 112 |
| Cost (€) | 960 | 960 | 960 | 960 | 960 | 960 | 960 | 6.720 |
| Motion Detectors (No.) | 75.00 | 25.00 | 25.00 | 25.00 | 75.00 | 90.00 | 65.00 | 380.00 |
| Cost (€) | 4,500,00 | 1,500,00 | 1,500,00 | 1,500,00 | 4,500,00 | 5,400,00 | 3,900,00 | 22,800,00 |
| Installation Motion Detectors (h) | 36 | 16 | 16 | 16 | 36 | 36 | 36 | 192 |
| Cost (€) | 1,920 | 960 | 960 | 960 | 1,920 | 1,920 | 1,920 | 1,920 |

| Bldg/Position | 7971 | 7973 | 7974 | 7975 | 7976 | 7977-2 | 7977-3 | Total Position |
|---|---|---|---|---|---|---|---|---|
| Hardware SC (€) | 3,000 | 3,000 | 3,000 | 3,000 | 3,000 | 3,000 | 3,000 | 21,000 |
| Program-ming/Connecting SC (h) | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 112 |
| Cost (€) | 960 | 960 | 960 | 960 | 960 | 960 | 960 | 6,720 |
| Implementing & Sys-tem Test (h) | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 112 |
| Cost (€) | 960 | 960 | 960 | 960 | 960 | 960 | 960 | 6,720 |
| Planning, Submission Costs. (h) | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 336 |
| Cost (€) | 4,800 | 4,800 | 4,800 | 4,800 | 4,800 | 4,800 | 4,800 | 33,600 |
| Assuming:<br>Labor Costs (€60/h)<br>Motion Detector: €60/piece)<br>Programmable Controller: €3,000/piece<br>Planning. Submission Costs, Project Management: €100/h | | | | | | | | |
| Total Investment (€) | 97,560 | | | | | | | |
| Reduction of costs/yr | 36,900 | | | | | | | |
| Return of Investment (yr) | 2.6 | | | | | | | |

### REN #22US – Solar wall, Bldgs 7950, 7951, 7954, 7955, 7971, and 7972

*Existing condition*

There are several warehouses at U.S. Army Depot – Germersheim that are well suited for a solar wall application. They all have a large expanse of wall on their south side of the building. These outside walls receive a lot of sunlight could be used for heating using solar energy (Figure 84). Warehouse Bldgs 7950, 7951 and 7954 are the same size and face the same direction. Warehouse Bldg 7955 is slightly smaller and it has a south facing wall similar to the others. All but 7954 are unheated buildings, but there are plans to heat them in the future. Warehouse Bldgs 7971 and 7972 are larger warehouses located in another area of the installation. Both are currently heated and 7972 has a wall that faces almost due south while 7971 southern wall is 30 degrees to the east. For these buildings all southern wall sections are 12 to 14 ft high by 210 to 220 ft long. The small warehouse Bldg 7955 has a southern wall that is 12-ft high by 180 ft long. These solar walls will provide heated ventilation air to these spaces.

Figure 84. Example of building proposed as candidate for solar wall.

*Solution*

The use of solar energy is desired for these facilities. The type of solar collector proposed is called a solar wall. A solar wall is a perforated wall placed a few inches outside of the buildings wall that receives a significant amount of sunlight. The sunlight heats the wall. Air is pulled from the cavity between the perforated wall and the building wall, which causes air to be drawn through the small openings in the outer wall. As air passes through the outer wall it is warmed. This solar heated air is brought into the building for use as ventilation air (Figure 85). In addition to the solar heat captured this wall also recovers heat that is conducted through this wall due to the temperature difference between inside and outside (Figure 86).

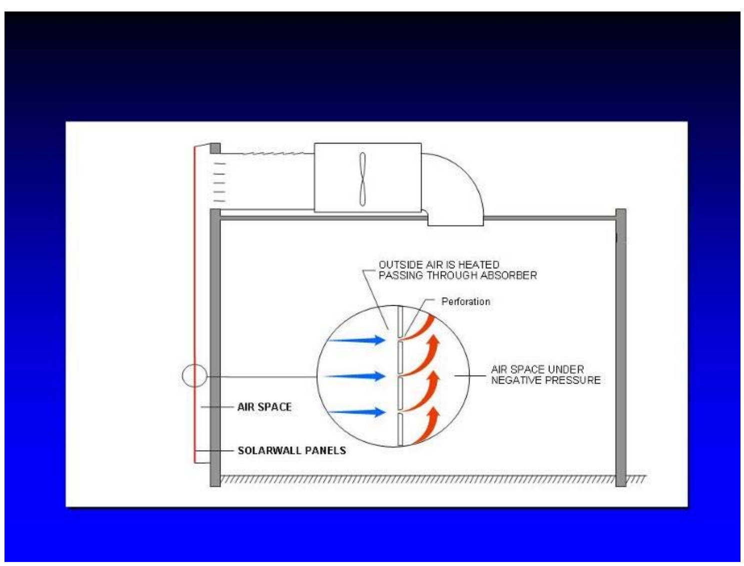


Figure 85. Solar wall depiction.

Figure 86. Building with solar wall.

Failure to use a solar wall on these buildings would result in a excessive heating energy use.

*Savings*

The results of a computer load simulation of this application for these buildings are provided in Table 54. As can be seen the solar wall will capture heat from the sun and it will also recover the building conduction losses for building through the southern wall. The total energy saved 326 million mWh of thermal energy could be collected.

Table 54. Results of a computer load simulation of this application for these buildings.

| Bldg. No. | South Wall Area. M | Solar Collector Size. Sq. M | Solar Energy Collected (mWh/yr) | Conductive Losses Collected (mWh/yr) | Total (mWh/yr) | Annual Energy Cost Savings |
|---|---|---|---|---|---|---|
| 7950 | 3.7 X 64 | 230 | 45.5 | 4.6 | 50.2 | 1847 |
| 7951 | 3.7 X 64 | 230 | 45.5 | 4.6 | 50.2 | 1847 |
| 7954 | 3.7 X 64 | 230 | 45.5 | 4.6 | 50.2 | 1847 |
| 7955 | 3.7 X 54.9 | 197 | 39 | 4 | 43 | 1582 |
| 7971 | 4.3 X 68.6 | 292 | 51.3 | 5.8 | 57.1 | 2101 |
| 7972 | 4.3 X 68.6 | 292 | 65 | 10.7 | 75.7 | 2786 |
| Total | | | 292 | 34 | 326 | 12,012 |

*Sample calculation*

Heating energy cost savings = 50.2 mWhth/yr * €36.8/mWhth/yr = €1,847/yr

*Investment*

Table 55 lists the cost of installing solar walls on these buildings. A solar wall typically has a cost of €230/$m^2$ installed. To deliver the heated air to the space inside the building a small air handling system is needed. The cost for this equipment is estimated to be €1.0/CFM. The total cost for all the solar wall systems is estimated to be €444,500.

Table 55. Cost of installing solar walls on 7950, 7951, 7954, 7955, 7971 and 7972.

| Bldg. No. | Collector Cost | AHU Cost | Total Cost | Payback Period |
|---|---|---|---|---|
| 7950 | 52,900 | 17,700 | 70,600 | 38.2 |
| 7951 | 52,900 | 17,700 | 70,600 | 38.2 |
| 7954 | 52,900 | 17,700 | 70,600 | 38.2 |
| 7955 | 45,310 | 17,700 | 63,010 | 39.8 |
| 7971 | 67,160 | 17,700 | 84,860 | 40.4 |
| 7972 | 67,160 | 17,700 | 84,860 | 30.5 |

*Payback*

Table 55 lists the resulting simple payback for each building. The best payback is over 30 yrs. The long payback is mainly due to these buildings being warehouses and thus their temperatures are kept lower than other buildings. This, in effect, shortens their heating season, which reduces the amount of energy cost savings.

### REN #23US – Install a windmill — Germersheim

*Existing conditions/problems*

To increase the amount of renewable energy and the self-sustainability it is in the interest of the U.S. Army to look into renewable alternatives. For Germersheim, which is an enduring facility for the U.S. Army in Germany, a windmill could be an interesting option.

*Solution*

Install a 2 MW windmill at the Germersheim facility. Connect it to the grid and purchase less energy from the power supplier.

*Savings*

A 2 MW windmill at Germersheim has the potential to generate 3,000 MWh of electricity/yr at 1,500 full load hrs/yr. At the current electricity rate, €8.93 cents/kWh, the value of the generated power is €268,000/yr. The annual maintenance and operational costs for the windmill are estimated to be €45,000/yr, making the net savings be €223,000/yr.

*Investment*

According to Reisi Windmonitor (http://reisi.iset.uni-kassel.de) the total investment cost is in the range of €1,000/kW or a total of €2 million for a 2 MW windmill.

*Payback*

The simple payback time for this investment is 9 yrs at current electricity prices. However, it is predicted that the costs of purchased electricity will increase, thus shortening the payback time.

**REN #24US–REN #28US – Photovoltaics U.S. Depot Germergheim**

The U.S. Depot in Germersheim has only a few buildings that fit into the PV selection criteria outlined in Chapter 3. Most of the buildings in Germersheim are warehouses with a very low inclination (less than 10 degrees, cf. Figure 87).

Figure 87. Typical warehouses at U.S. Depot Germersheim.

Only the buildings with acceptable orientations and inclinations are recommended to be used for PV-systems. Some buildings appropriate for PV-Systems are in a bad construction condition. The roofs should be retrofitted before PV-Systems will be installed on it, therefore these buildings are not evaluated.

The Fire Brigade building is a new construction with a nearly flat roof that is appropriate for a free-standing PV-System.

There is no Open Space in Germersheim for free-standing ground-placed PV-Systems.

All calculations are to be seen as orientations within a bandwidth of +/-5 percent.

Cable length, specific construction issues, inclination data, PV-areas of the roof, the number of modules are in some cases estimated figures and due to these estimates the results per building may change within this bandwidth.

The buildings that are evaluated are marked in the site plan (Figure 88).

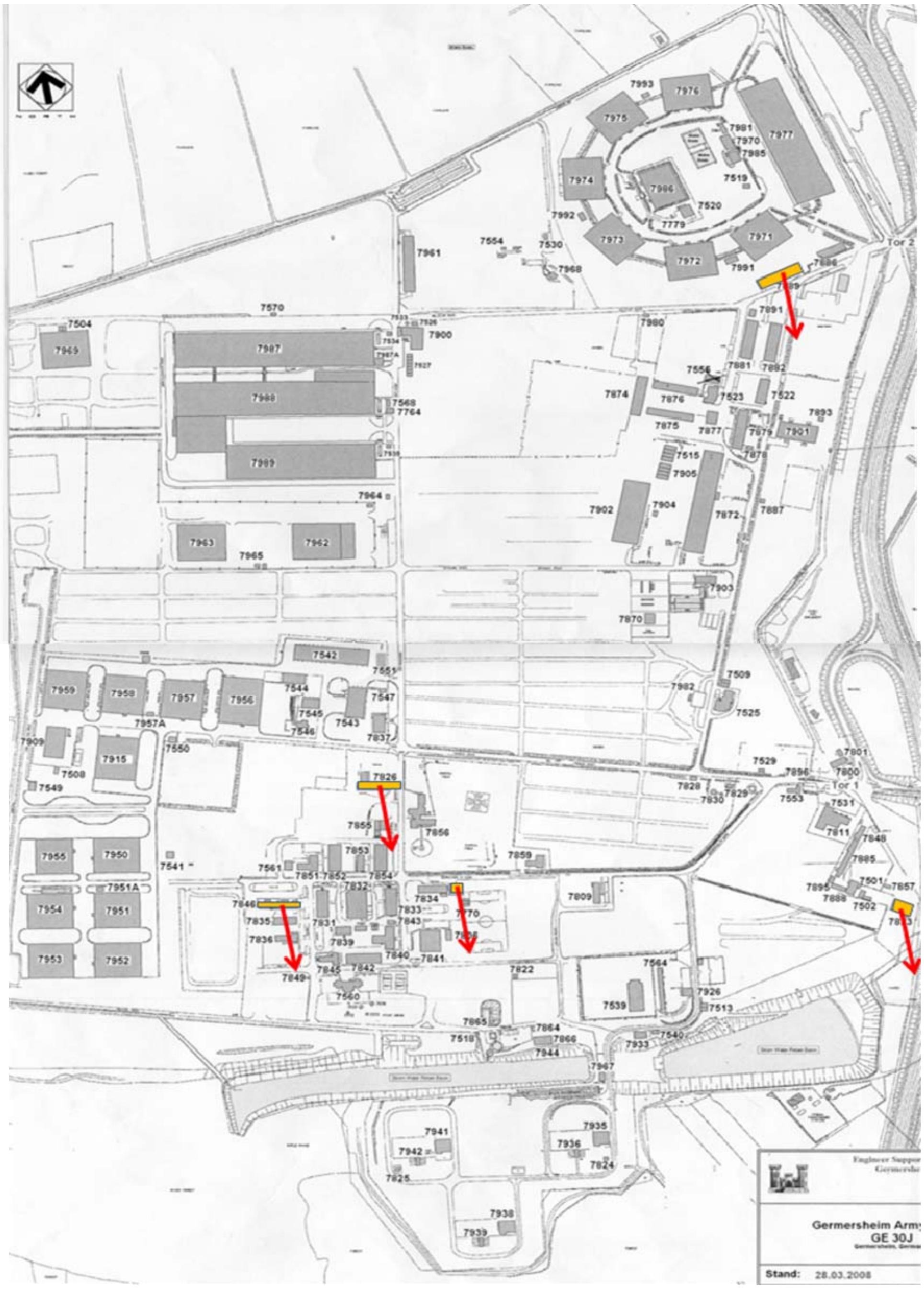

Figure 88. Site plan Germersheim with marked buildings.

### REN #24US PV Bldg 7889 — Germersheim

Figure 89 shows and the data in Table 56 describe Bldg 7889 (Warehouse) at Germersheim.


Figure 89. Bldg 7889/Warehouse – Germersheim.

Table 56. Overview example PV-System – Bldg 7889 Germersheim.

| Parameter | Measure | Remarks |
|---|---|---|
| Location | Germersheim | |
| Footprint | 15 m x 65 m | |
| Roof Characteristic | Ridge Roof | |
| Inclination | 17 degrees | |
| Orientation | 180 degrees | |
| Area of PV-System | 390 $m^2$ | |
| No. of Modules | 600 | |
| Output | 48 kWp | |
| Roof Load/$m^2$ | 17.5 kg | |
| Estimated yearly results | | |
| Specific Annual Yield | 970 kW/kWp | Approximately 10% higher than shown in Figure 8 |
| Grid Feed-in/yr | 46,503 kWh | First year/Degradation: 5% in 20 yrs |
| Total Revenue (20-yr period) | €416,861 | Installation End 2008 |
| Total Revenue (20,5-yr period) | €406,153 | Installation Mid 2009 |
| Investment Cost | €218,208 | Total Investment costs including installation |
| Investment Cost/kWp | €4,546 | |
| Break even time (without capital cost) | 10/11 yrs | Installation 2008/2009 |
| Liquidity cumulated (with capital cost) | €95,739/€85,031 | Installation 2008/2009 |
| Real rate of return | 44%/39% | Installation 2008/2009 |
| $CO_2$ Reduction cumulative | 299 t/307 t | Installation 2008/2009 |

### REN #25US – PV Bldg 7823 — Germersheim

Figure 90 shows and the data in Table 57 describe Bldg 7823 (a Maintenance building) at Germersheim.

Figure 90. Bldg 7823/Maintenance – Germersheim.

Table 57. Bldg 7823 PV-system – Germersheim.

| Parameter | Measure | Remarks |
|---|---|---|
| Location | Germersheim | |
| Footprint (approx) | 50 m x 15 m | |
| Roof Characteristic | Ridge Roof | |
| Inclination | 33 degrees | |
| Orientation | 139 degrees | |
| Area of PV-System | 450 m² | |
| No. of Modules | 700 | |
| Output | 56,35 kWp | |
| Roof Load/m² | 17.5 kg | |
| Estimated yearly results | | |
| Specific Annual Yield | 974 kW/kWp | |
| Grid Feed-in/yr | 54,872 kWh | First year/Degradation: 5% in 20 yrs |
| Total Revenue (20-yr period) | €489,619 | Installation End 2008 |
| Total Revenue (20.5-yr period) | €477,049 | Installation Mid 2009 |
| Investment Cost | €265,167 | Total Investment costs including installation |
| Investment Cost/kWp | €4,546 | |
| Break even time (without capital cost) | 10/11 yrs | Installation 2008/2009 |
| Liquidity cumulated (with capital cost) | €115,635/ €100,064 | Installation 2008/2009 |
| Real rate of return | 44.0%/39.1% | Installation 2008/2009 |
| $CO_2$ Reduction cumulative | 354 t/363 t | 20-yr period |

### REN #26US – PV Bldg 7834 — Germersheim

Figure 91 shows Bldg 7834 (Fire Brigade) at Germersheim. Figure 92 shows and the data in Table 58 describe the proposed positioning PV-System for that building.

Figure 91. Bldg 7834/Fire Brigade – Germersheim.

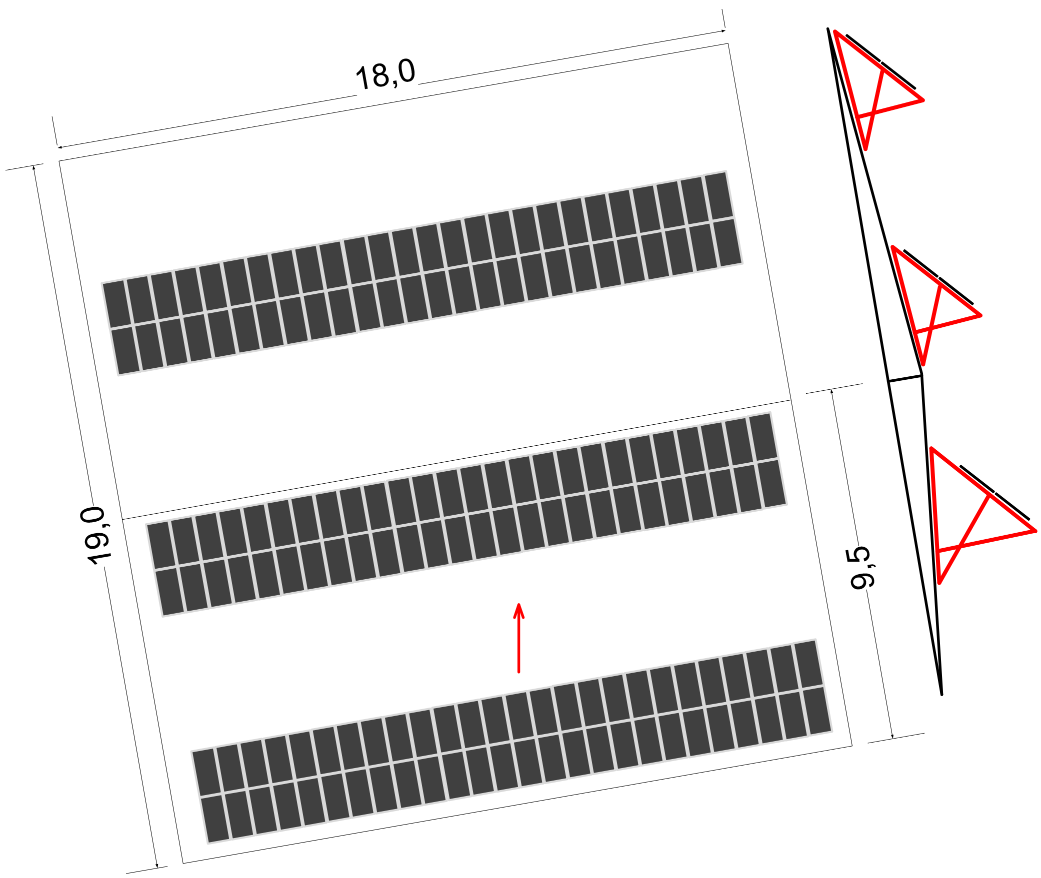


Figure 92. Bldg 7834/Fire Brigade – positioning PV-system.

Table 58. Bldg 7834 PV-system – Germersheim.

| Parameter | Measure | Remarks |
|---|---|---|
| Location | Germersheim | |
| Footprint (Approximate | 19 m x 18 m | |
| Roof Characteristic | Flat Roof | Free-standing PV-System |
| Inclination | 35 degrees | |
| Orientation | 170 degrees | |
| Area of PV-System | 121 $m^2$ | |
| No. of Modules | 168 | |
| Output | 13.52 kWp | |
| Roof Load/$m^2$ | 19.25 kg | 10% mark up because of carrier system |
| Estimated Yearly Results | | |
| Specific Annual Yield | 993 kW/kWp | |
| Grid Feed-in/yr | 13,346 kWh | First year/Degradation: 5% in 20 yrs |
| Total Revenue (20-yr period) | €122,690 | Installation End 2008 |
| Total Revenue (20,5-yr period) | €119,533 | Installation Mid 2009 |
| Investment Cost | €64,535 | Total Investment costs including installation |
| Investment Cost/kWp | €4,773 | 5% mark up because of carrier system |
| Break Even Time (without Capital Cost) | 10/11 yrs | Installation 2008/2009 |
| Liquidity Cumulative (with Capital Cost) | €27,718/€24,561 | Installation 2008/2009 |
| Real Rate of Return | 43.0%/38.1% | Installation 2008/2009 |
| $CO_2$ Reduction Cumulative | 87 t/89 t | 20-yr period |

### REN #27US – PV Bldg 7846 — Germersheim

Figure 93 shows and the data in Table 59 describe Bldg 7846 (the Shopette) at Germersheim.


Figure 93. Bldg 7846/Shopette – Germersheim.

Table 59. Bldg 7846 PV-system – Germersheim.

| Parameter | Measure | Remarks |
|---|---|---|
| Location | Germersheim | |
| Footprint (Approximate) | 93 m x 12 m | |
| Roof Characteristic | Ridge Roof | |
| Inclination | 17 degrees | |
| Orientation | 164 degrees | |
| Area of PV-System | 500 $m^2$ | |
| No. of Modules | 700 | |
| Output | 56.35 kWp | |
| Roof Load/$m^2$ | 17.5 kg | |
| Estimated Yearly Results | | |
| Specific Annual Yield | 975 kW/kWp | |
| Grid Feed-in/yr | 54,931 kWh | First year/Degradation: 5% in 20 yrs |
| Total Revenue (20-yr period) | €490,150 | Installation End 2008 |
| Total Revenue (20,5-yr period) | €477.566 | Installation Mid 2009 |
| Investment Cost | €256,167 | Total Investment costs including installation |
| Investment Cost/kWp | €4,546 | |
| Break even time (without capital cost) | 10/11 yrs | Installation 2008/2009 |
| Liquidity cumulated (with capital cost) | €113,165/ €100,581 | Installation 2008/2008 |
| Real rate of return | 44.2%/39.3% | Installation 208/2009 |
| $CO_2$ Reduction cumulative | 354 t/363 t | 20-yr period |

### REN #28US – PV Bldg 7826 — Germersheim

Figure 94 shows and the data in Table 60 describe Bldg 7826 (the Post Office) at Germersheim.


Figure 94. Bldg 7826/Post Office – Germersheim.

Table 60. Bldg 7826 PV-system – Germersheim.

| Parameter | Measure | Remarks |
|---|---|---|
| Location | Germersheim | |
| Footprint (Estimated) | 70 m x 16 m | |
| Roof Characteristic | Ridge Roof | |
| Inclination | 22 degrees | |
| Orientation | 170 degrees | |
| Area of PV-System | 560 m² | Reductions because of roof windows |
| No. of Modules | 780 | |
| Output | 62.79 kWp | |
| Roof Load/m² | 17.5 kg | |
| Estimated Yearly Results | | |
| Specific Annual Yield | 991 kW/kWp | |
| Grid Feed-in/yr | 62,229 kWh | First year/Degradation: 5% in 20 yrs |
| Total Revenue (20-yr period) | €553,756 | Installation End 2008 |
| Total Revenue (20,5-yr period) | €539,543 | Installation Mid 2009 |
| Investment Cost | €285,443 | Total Investment costs including installation |
| Investment Cost/kWp | €4,546 | |
| Break even time (without capital cost) | 10/11 yrs | Installation 2008/2009 |
| Liquidity Cumulated (with Capital Cost) | €133,688/ €119,475 | Installation 2008/2009 |
| Real Rate of Return | 46.8%/41.9% | Installation 2008/2009 |
| $CO_2$ Reduction Cumulative | 401 t/411 t | 20-yr period |

## ECMs Applying to Multiple Facilities

### MUL #1 – Add buildings to the UEMCS building control system

*Existing conditions/problems*

There is an excellent system in operation in Heidelberg and for several buildings at Campbell Barracks. The Utility Energy Monitoring and Control System (UEMCS) system is operated from a central control room at Campbell and it is an efficient tool to keep energy use in control although it does not (as all EMCS systems) eliminate the need for visual checks. The number of buildings and systems connected to the UEMCS is limited (present system has 26,000 data points) to far too few buildings and could be expanded.

*Solution*

Add more buildings to the system.

*Savings*

There is so much unknown with the status of existing building controls (both those connected to the UEMCS and those not connected) that it is reasonable to say that the potential savings in major buildings could be in the range of 15 – 20 percent regarding heating, electricity for cooling and motors. Comfort improvements can be made easily with working building controls. Maintenance costs can be reduced substantially, but of course not entirely.

*Investment*

Investment is estimated to be several million dollars, depending on how many buildings will be included in the system. A recent study at Fort Bliss, TX[*] summarized the costs to include 35 buildings into existing Utility Monitoring and Control System (UMCS) and to upgrade and integrate several systems into one system to be approximately $90,000/building.

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[*] David M. Underwood, Alexander M. Zhivov, James P. Miller, Alfred Woody, Robert Colbert, Leon Shapiro, Curt Bjork, William D. Chvala, Jr., and Douglas Dixon. 2008. *Energy Optimization Assessment at U.S. Army Installations: Fort Bliss, TX*. ERDC/CERL TR-08-15. Champaign, IL: ERDC. Champaign, IL: Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL).

*Payback*

Normally, the resulting payback will occur within 5 yrs of operation after everything is commissioned, tested, and verified. With a 1- to 2-yr installation and commissioning period, the investment should be paid back after 7 yrs from awarding the contract, assuming the system "starts from scratch." Using the existing UEMCS system should further reduce the payback period.

### MUL #2 – Re-commission building controls and HVAC systems

*Existing conditions/problems*

Existing building controls in many cases have deteriorated to the point that they are not functioning appropriately. This includes AHUs, boilers, chillers, and perimeter heat systems. Sequences of operation do not match the way buildings and spaces are used today. Set points for temperature and air flow need to be revised. Control functions such as economizing modes with outdoor and return air dampers in sequence and no longer function according to initial design and construction. Signals from temperature, static pressure, and other sensors are not calibrated. Some systems are controlled by outdated pneumatic controls. Although some people might prefer pneumatic systems, they are not as accurate as DDC controls, and also need working air compressors to function. The air compressors also use electric energy and require maintenance, which increases the operating costs.

A typical Energy Management Control System (EMCS) consists of a central computer and many measurement and control points that activate or modulate fans, dampers, pumps, coils, chillers, boilers and other HVAC equipment. Programmed into that system are many schedules, sequences of operation, and control schemes designed to maintain comfort while trimming energy costs. For savings to occur however the programming must be correct (without conflicts, such as simultaneous heating and cooling), and all measuring devices (e.g., temperature sensors) and actuators must be working as designed. As with links in a chain failure at one level makes the rest essentially irrelevant.

When an EMCS is installed, it is usually tested to ensure it will deliver comfortable conditions, but its operation may not be verified with regard to optimal energy efficiency. To ensure an EMCS will deliver promised savings it needs to be commissioned on installation or retro-commissioned thereafter.

An EMCS and its control points need to be retro-commissioned if one finds the following:

- unusually high energy use
- chronic failures of building equipment, the control system, or both
- numerous and growing comfort problems.

*Solution*

Refer back to original specifications and design and compare them to the building's previous use and re-design to match the building's current needs, occupancy level, and type of use. Choose only such buildings that have a remaining life expectancy of 5 yrs or more. Check every signal and function and validate that the functions are available. Fix whatever needs to be fixed. Make sure simultaneous heating and cooling can never occur by programming new sequences and blocking use of units that can cause the simultaneous heating and cooling. Set alarm points for important signals such as high temperatures, low temperatures, damper failure, pressure too high or too low etc. Troubleshoot all the AHUs and their respective functions. Log dampers, temperatures, actuator signals, and other parameters to identify problems. Adjust chiller and boiler set points and control curves. Replace malfunctioning hardware and adjust software. Implement night and weekend temperature setback. Optimize economizer modes/cycles. Check variable air volume (VAV) boxes, VFDs, pressure sensors, and controls. More specific things to fix should also include:

1. Insulating pipes and duct work; temperature increases in summer and temperature drops in winter are not negligible
2. Repairing or replacing all failing equipment, e.g., non-operating dampers, controls out of control, 100 percent OA instead of 100 percent return air (RA), all of which indicate substantial energy waste.
3. Adjusting building air and water flows to designed values.

*Savings*

Savings from proper commissioning or later retro-commissioning will range widely depending on how well systems were designed, installed, and maintained before review. Independent studies have shown cuts in energy costs ranging from 3 to 50 percent with paybacks for commissioning ranging from 3 months to 5 yrs.

*Investment*

Due to variations among buildings and systems, costs for commissioning or retro-commissioning services vary widely from $0.03 to $0.43/sq ft with $0.20/sq ft being a generally accepted average. That cost typically encompasses review of all EMCS programming, testing of all measurement and control points, identification of all problems, minor repairs and a short-term verification of savings.

*Payback*

The resulting payback will occur in less than 5 yrs.

**MUL #3 – LED lighting systems**

LED technology is on its way to replace the fluorescent tubes. Currently, this innovative technology is only applicable to very specific applications, e.g., in living areas or, in industry, in typical office areas. It is likely that intensive R&D efforts will broaden LED applications in the next 2–4 yrs. The following example shall demonstrate the electricity saving potential by using the LED technology.

Approximately 24 office and meeting rooms in typical sizes are located in Bldg 7522 (Figures 95 and 96). Each office or meeting room is equipped with four florescent lights (each with two tubes of 36 W). The operation time is approx 9 hrs/day, 5 days/wk.

Figure 95. Bldg 7522 – Germersheim.

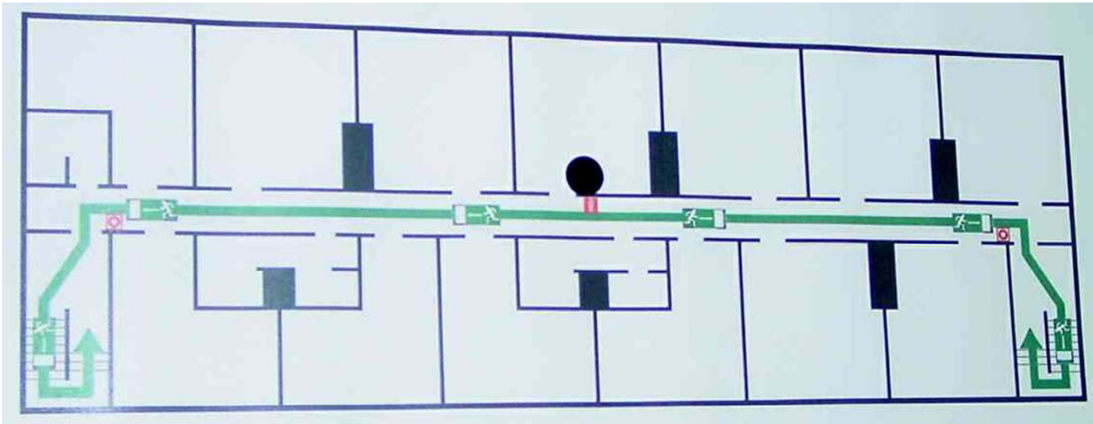

Figure 96. Floor plan/Bldg 7522 – Germersheim.

*Office room Bldg 7522*

Table 61. Light electricity saving potential with LED-technology.

| No. of rooms/aisle | Fluorescent Tubes/room or aisle | Total Power installed (kW) | Operation time/yr | Total Light Electricity Consumption/yr (kWh) | Light Electricity Costs/yr (0.08 €/kWh) | Saving Potential with LED Technology/yr | Light Electricity Costs with LED Technology/yr |
|---|---|---|---|---|---|---|---|
| 24 | 8 | 6.1 | | | | | |
| 2 | 10 | 0.7 | | | | | |
| | | 6.8 | 1,800 | 12,240 | 979 | 70% | 293 |

The electricity saving potential with the LED technology is with the actual technical performance of LEDs on a level of approximately 50 – 60 percent of the normal florescent tubes (Table 61). These saving potentials were demonstrated in the Nimbus Germany labs. The following Figure 97 and 98 show the results of the Q 64 lighting system (with 64 LEDs), which can replace a typical office light (2 x 36 W fluorescent tubes).

Figure 97. Q 64 – LED office light demonstrated at Nimbus Labs, Germany.

Figure 98. Comparison of electricity consumption fluorescent tubes with LED technology.

The meters shown in Figure 98 indicate that, for smaller light applications, the saving potential are even higher. The value on the left side represents the energy consumption of a florescent application, and the value on the right side, the energy consumption of an application with LED technology. The light intensity is identical for both cases.

*LED Technology – conclusion and recommendation*

All suppliers of LED Lighting systems admit the current technology status does not allow competing with florescent tubes in larger buildings. The LED light intensity is to low for an installation in shopping centers warehouses or other similar facilities. However, LED light systems are applicable in smaller rooms (cf. Figure 97), aisles, building stairways, or in special applications with spotlight characteristics or other comparable industrial applications.

LED suppliers predict that, in about 3 to 5 yrs, it will be possible to replace florescent tubes on a larger scale with LED technology. When this becomes possible, warehouses using LED technology may potentially reduce their electrical consumption due to lighting by approximately 50 percent or more by combining LED lighting with automated on/off switch controls. Table 62 lists the projected costs to light Bldg 7977 (1 – 3) existing technology, the designs included in the project proposal, and the proposed project augmented with LED technology.

Table 62. Saving potential of LED technology.

| | Electricity consumption (MWh/yr) | Electricity costs (€) |
|---|---|---|
| Existing Situation | 597 | 47,760 |
| Results with Project Proposal | 301 | 24,130 |
| Results with Project Proposal and LED Technology | 150 | 12,040 |

LED technology has a much longer lifespan than florescent tubes. LEDs have a predicted lifespan of approximately 50,000 hours at a constant light intensity, after which the light intensity may decrease. Switching (on/off) does not affect the life time, but does lower maintenance costs. It is highly recommended that planners follow the development of LED technology to be able to take advantage of the great power-saving opportunity when it arrives.

### MUL #4 – Optimize compressed air use and compressor size in Bldg 4 at Coleman Barracks and Bldg 7902 at Germersheim

This Multiple ECM is described in detail as:

- HVAC #6CO (p 75)
- HVAC #9US (p 121).

### MUL #5 – Replacement of circulation pumps

The number of installed circulation pumps (Figure 99) in the Garrisons where the energy assessments were performed is unknown. Assuming that each building with a heating system has at least three circulation pumps, then the total number of installed circulation pumps is about 1,000 pumps.

The assessments show that only a few pumps as are new or at an high energy efficiency standard. The diagram in Figure 100 shows the differences in energy consumptions between the a standard and high efficiency pump:

- Energy consumption standard pump 1,832 kWh/yr
- Energy consumption high efficiency pump 396 kWh/yr.

Figure 99. Example heating circulation pumps.

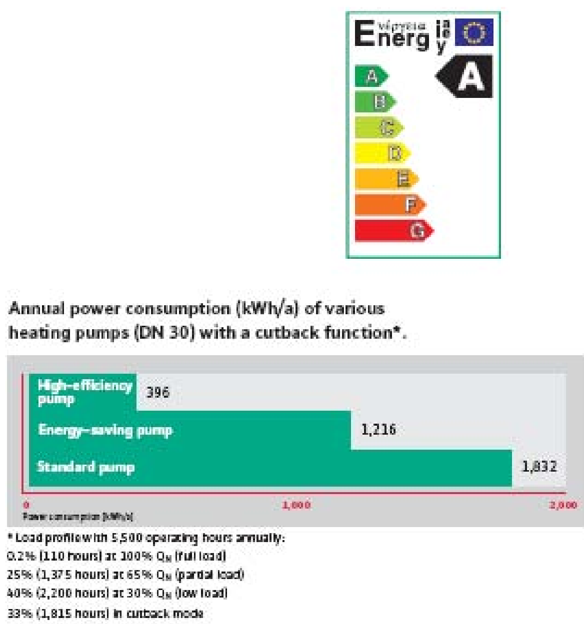


Figure 100. Efficiency comparison of different circulation pumps.

Based on an electricity price of €0.08/kWh, the saving potential for each pump of this size is at approximately €110/yr or 80 percent.

The cost of a high efficiency pump of this size is about €300. This results in an amortization time of approximately 3 yrs.

Appendix B to this report (available electronically) includes the price list of Wilo Germany and shows the prices for the high efficiency circulation pumps and a replacement list (Appendix C) with recommendations regarding which old pump can be replaced by which new pump type. Figure 101 shows examples of two pump types.

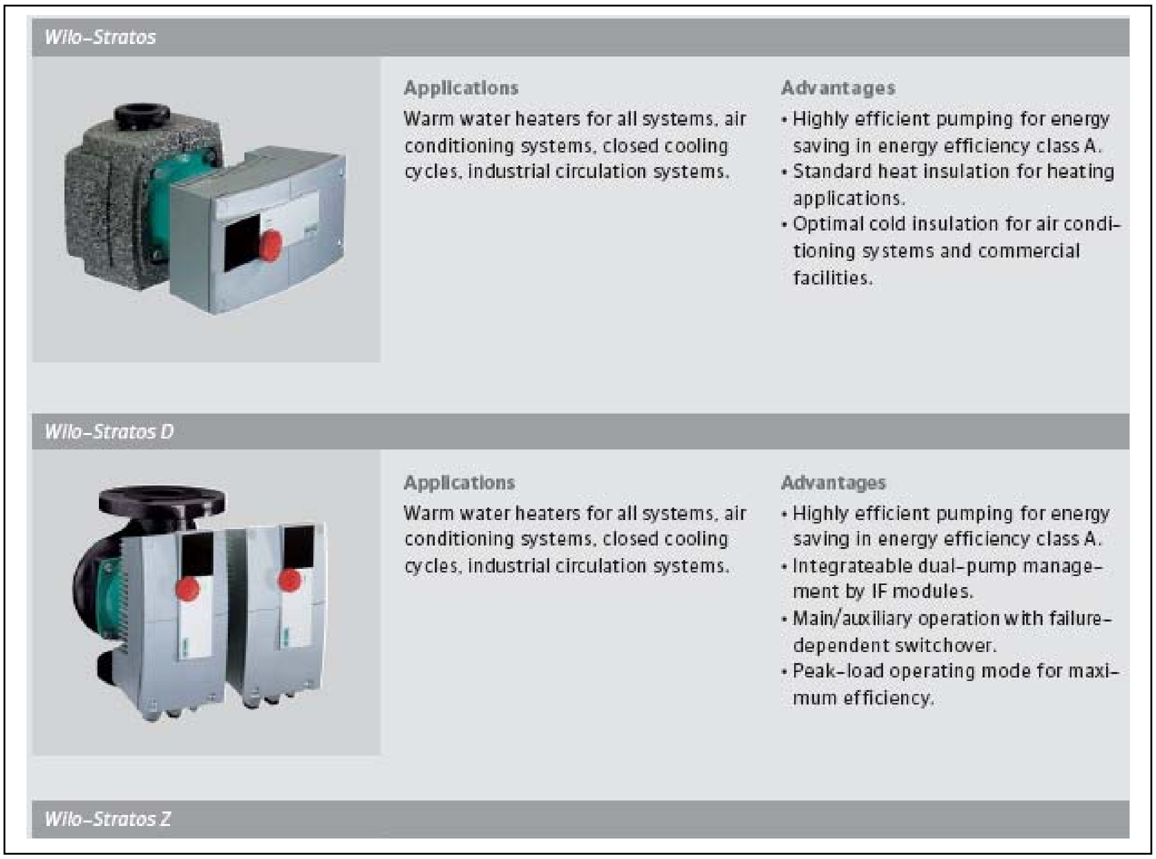


Figure 101. WILO energy efficiency Class A circulation pumps.

### MUL #6 – Switch off boilers, HW pumps, and chillers based on OA temperature (example Bldg 18 Campbell Barracks and Bldgs 49, 106 at Coleman Barracks)

*Existing conditions/problems*

At Campbell Barracks in Heidelberg and at Coleman Barracks in Mannheim, during the energy assessment in May 2008, it was found that some HW pumps were running, circulating hot water to unit heaters air handling units and radiators that had no heat demand due to the high outdoor air temperature. This was the fact in Bldg 18 at Campbell Barracks and Bldgs 49 and 106 at Coleman Barracks. In the Shoppette at Bldg 25 Coleman Barracks, 135 °F hot water was circulated through unit heaters at the same time as the chiller supplying cold air into the space was running.

Running these pumps when there is no need for heat or cooling wastes electric energy used for pump motors, and energy lost when chilled or hot water circulates idly around buildings. This condition could easily be detected by studying the delta-T difference between supply and return temperatures in the mechanical rooms where the pumps where located; only a 1–2 °C ΔT was noted during the site visit.

*Solution*

Add the following commands to existing DDC controls supervised and controlled also through the EMCS:

- Chillers and chilled water pumps stop when OA is below 60 °F, and start (in reverse sequence) when OA is above 60 °F. (Note that 65 °F would be an even more efficient start temperature).
- Boilers (local boilers like in Bldg 330) and hot water pumps stop when OA is above 60 °F, start in reverse sequence when OA drops below 60 °F.

Personnel at Coleman Barracks indicated that no decision had yet been made this year when to switch the heat off, and that, in most cases, it must be done manually.

*Savings*

The savings here are illustrated by an example from Coleman Barracks. Assume two 25 hp hot water pumps running during warm days. Assume that pump motors are loaded 80 percent, which gives a total electric load for the HW pumps to be 40 hp.

The present settings allow pumps boilers and chillers to run simultaneously and far too many hours/yr (without needs). Without knowing exactly how much, a rough estimate assumed 200 hrs generating unnecessary electricity use:

40 * 0.746 kW/hp * 200 hrs = 6,000 kWh/yr worth €540

Adding all running pumps is estimated to sum up to at least 10 times as much for Campbell and Coleman together, with the majority at Coleman. Total savings by switching off pumps then is 60,000 kWh worth of electricity or €5,400.

Even larger savings will come from heat savings (all the heat that is pumped around now, generating losses in pipes and AHUs) and cooling savings (chillers run to remove the extra heat that is supplied to buildings via unit heaters, pipes, air handling units with heat circulating through coils [leaking control valves] etc.).

*Investment*

The investment required to re-program controls should cost no more than €100/mechanical room. Manually switching off pumps is already part of the normal work done by DPW personnel.

*Payback*

The resulting payback will occur within 0.3 yrs.

## Summary

Table 63 summarizes ECMs that apply to multiple facilities.

Table 63. Summary of ECMs that apply to multiple facilities.

| ECM # | ECM Description | Electrical Savings | | Thermal | | Maintenance €/yr | Total Savings: Electrical Use, Elec Demand, Thermal, and Maint (€/yr) | Investment € | Simple Payback yrs |
|---|---|---|---|---|---|---|---|---|---|
| | | KWh/yr | €/yr | MMBtu/yr | €/yr | | | | |
| MUL #1 | Add Buildings to the UEMCS Building Control System | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - |
| MUL #2 | Re-commission Building Controls and HVAC systems | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MUL #3 | LED Lighting Systems | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - |
| MUL #4 | Optimize Compressed Air Use and Compressor Size Bldg 7902 at Germersheim and Bldg 4 at Coleman Barracks | 175,000 | 15,628 | 0 | 0 | 0 | 15,628 | 40,000 | 3 |
| MUL #5 | Replacement of Circulation Pumps | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - |
| MUL #6 | Switch off boilers, HW pumps, and Chillers Based On Outside Air Temperature Bldg 18 Campbell Barracks and Bldgs 49, 106 at Coleman Barracks | 60,000 | 5,358 | 0 | 0 | 0 | 5,358 | 0 | 0 |
| *Totals* | | *235,000* | *€20,986* | *0* | *€0* | *€0* | *€20,986* | *€40,000* | *1.9* |

# 5 Summary, Recommendations, and Lessons Learned

## Summary

This study performed an Energy Optimization Assessment at several Army installations (Campbell Barracks—Heidelberg, Coleman Barracks—Manheim, Katterbach Barracks—Ansbach, Storch Barracks—Illesheim, and U.S. Army Depot—Germersheim) as a part of the Annex 46 showcase studies to identify energy inefficiencies and wastes, and to propose energy-related projects with applicable funding and execution methods that could enable the installations to better meet the energy reduction requirements mandated by Executive Order 13423 and EPACT 2005. The study was limited to the Level I assessment; its scope included an analysis of building envelopes, ventilation air systems, controls, central heating plants, interior and exterior lighting, and an evaluation of opportunities to use renewable energy resources.

The study identified 87 different potential energy conservation measures (ECMs) (Table 64). If all were implemented, these ECMs would result in savings of ~€1.7 million/yr (9,331 MWh/yr in electrical energy savings and 27,545 MMBtu/yr in thermal savings). Implementation of these projects would require an investment of €14.8 million. Renewables, Central Energy Plants (CEP), Radiant Heating, Lighting, and HVAC had the largest cost savings of the facilities visited. In addition to the ECMs discussed in this report, this work also investigated the potential for solar heating of domestic hot water. However, due to the long paybacks (in excess of 20 years), these ECMs are included as Appendix A. Several opportunities such as optimization of CEPs are applicable to almost any installation in Germany, so the potential summarized here is a small fraction of the total potential.

The best opportunities, as judged simple payback (investment divided by yearly savings), were found in ECMs that apply to all facilities (referred to as “Multiple” [MUL] in Table 64), Central Energy Plants, and HVAC. All had aggregate paybacks of less than 4 years. ECMs for dining facilities also had very good paybacks with an aggregate simple payback of 5.5 years.

Table 64. All identified potential ECMs.

| ECM | ECM Description | Electricity Savings | | | Thermal | | Maintenance €/Yr | Total Savings: Electrical Use, Elec Demand, Thermal, and Maint €/Yr | Investment € | Simple Payback Years |
|---|---|---|---|---|---|---|---|---|---|---|
| | | MMBtu/Yr | KWh/yr | €/Yr | MMBtu/Yr | €/Yr | | | | |
| BE #1CO | Install Panels in Areas Having Single Pane Windows, Bldg 25 | 0 | 0 | € 0 | 124 | € 1,336 | 0 | € 1,336 | € 19,800 | 14.8 |
| BE #2CO | Reduce Door Size, Bldg 49 | 0 | 0 | € 0 | 290 | € 3,132 | 0 | € 3,132 | € 44,500 | 14.2 |
| BE #3US | Reduce Door Size Bldgs 7938 and 7941 | 0 | 0 | € 0 | 232 | € 2,499 | 0 | € 2,499 | € 30,300 | 12.1 |
| DIN #1CA | Utilize Kitchen Hood Control, Bldg 112 | 91 | 26,630 | € 2,378 | 458 | € 4,938 | 0 | € 7,316 | € 42,200 | 5.8 |
| DIN #2CO | Modify Kitchen Hoods with End Skirts and Temperature Controlled Exhaust, Bldg 45 | 87 | 25,400 | € 3,629 | 240 | € 2,588 | 0 | € 6,217 | € 40,600 | 6.5 |
| DIN #3CO | Use Low Flow Pre-Rinse Kitchen Nozzles | 0 | 0 | € 0 | 146 | € 1,574 | 0 | € 1,574 | € 80 | 0.1 |
| CEP #1CA | Analysis of the Secondary Heating System Pumps, Adjustment of the Size and Operation Mode | 0 | 2,700 | € 241 | 0 | 0 | 0 | € 241 | € 2,500 | 10.4 |
| CEP #2CA | Additional Bio-Diesel-Fired Cogeneration Motor | 0 | 2,250,000 | 0 | 10,239 | 0 | € 28,362 | € 171,000 | € 449,000 | 15* |
| CEP #3CA | Optimization of the Central Cooling System | 0 | 0 | 0 | 314 | € 26,900 | 0 | € 26,900 | € 343,000 | 12.8 |
| CEP #4CO | Substation Optimization - Coleman Barracks | 0 | 136,080 | € 27,216 | 0 | 0 | 0 | € 27,216 | € 45,000 | 1.7 |
| CEP #5US | Connection of the “Big O” Buildings to the Central Heating System | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| HVAC #1CA | Repair Leaking Hot Water Valve, Bldg 18 | 536 | 157,000 | € 14,020 | 1,611 | € 17,370 | 0 | € 31,390 | € 2,000 | 0.1 |
| HVAC #2CA | Adjust HVAC Unit Outdoor Air Using $CO_2$ sensors, Bldg 22 | 16 | 4,800 | € 429 | 505 | € 5,446 | 0 | € 5,875 | € 4,000 | 0.7 |
| HVAC #3CA | Modify Building Controls To Allow HVAC Unit Not Use 100% Outside Air, Bldg 18 | 82 | 23,900 | € 2,134 | 2,536 | € 27,342 | 0 | € 29,477 | € 1,000 | 0.0 |
| HVAC #4CA | Install Absorption Chiller Driven by Solar Collectors To Replace Electric Chiller - Bldg 3983 | 0 | 89,000 | € 7,948 | 0 | € 0 | 0 | € 7,948 | € 240,000 | 30.2 |
| HVAC #5CO | Reduce Pressure and Recover Waste Heat from Air Compressor, Motor Pool Bldg 57 | 10 | 2,860 | € 255 | 20 | € 221 | 0 | € 476 | € 1,000 | 2.1 |
| HVAC #6CO | Optimize the Use of Compressed Air and the Sizing of the Air Compressors – Hanger Bldg 4 | 444 | 130,000 | € 11,609 | 0 | € 0 | 0 | € 11,609 | € 25,000 | 2.2 |
| HVAC #7CO | Replace Pneumatic Controls with DDC Bldg 4 | 0 | 0 | € 0 | 2,048 | € 22,080 | 0 | € 22,080 | € 150,000 | 6.8 |
| HVAC #8US | Check Temperature Control and Check OA Damper Functions for Unit Heaters Bldg 7902 | 0 | 0 | € 0 | 341 | € 3,680 | 0 | € 3,680 | € 5,000 | 1.4 |
| HVAC #9US | Curt Optimize the Use of Compressed Air and the Sizing of the Air Compressors – Motor Pool Bldg 7902 Germersheim | 154 | 45,000 | € 4,019 | 0 | € 0 | 0 | € 4,019 | € 15,000 | 3.7 |
| LI #1CA | Use Occupancy Sensors To Turn off Lights | 4 | 1,272 | € 114 | 0 | € 0 | 0 | € 114 | € 1,100 | 9.7 |
| LI #2CA | Change Bulbs in Exit Lights | 60 | 17,520 | € 1,565 | 0 | € 0 | € 2,400 | € 3,965 | € 18,000 | 4.5 |
| LI #3CO | Use Occupancy Sensors To Turn off Lights | 77 | 22,633 | € 2,021 | 0 | € 0 | 0 | € 2,021 | € 11,500 | 5.7 |

| ECM | ECM Description | Electricity Savings | | | Thermal | | Maintenance €/Yr | Total Savings: Electrical Use, Elec Demand, Thermal, and Maint €/Yr | Investment € | Simple Payback Years |
|---|---|---|---|---|---|---|---|---|---|---|
| | | MMBtu/Yr | KWh/yr | €/Yr | MMBtu/Yr | €/Yr | | | | |
| LI #4CO | Change Bulbs in Exit Lights | 119 | 34,950 | € 3,121 | 0 | € 0 | € 4,800 | € 7,921 | € 36,000 | 4.5 |
| LI #5CO | Reduce Lighting Using Day Lighting Controls, Band Lobby Area, Bldg 25 | 1 | 250 | € 22 | 0 | € 0 | 0 | € 22 | € 400 | 17.9 |
| LI #6CO | Reduce Lighting Using Day Lighting Controls, Storage area Bldgs 49 | 15 | 4,310 | € 385 | 0 | € 0 | 0 | € 385 | € 64,000 | 166.3 |
| LI #7CO | Shut Off Outdoor Lighting in Daytime, Bldg 57 | 4 | 1,235 | € 110 | 0 | € 0 | 0 | € 110 | € 300 | 2.7 |
| LI #8CO | Add Skylights, Bldg 49 | 49 | 14,400 | € 1,286 | 0 | € 0 | 0 | € 1,286 | € 51,000 | 39.7 |
| LI #9CO | Change Bulbs in Exit Lights | 119 | 34,950 | € 3,121 | 0 | € 0 | € 4,800 | € 7,921 | € 36,000 | 4.5 |
| LI #10CO | Reduce Lighting Using Day Lighting Controls, Band Lobby Area, Bldg 25 | 1 | 250 | € 22 | 0 | € 0 | 0 | € 22 | € 400 | 17.9 |
| LI #11CO | Reduce Lighting Using Day Lighting Controls, Storage Area Bldgs 49 | 15 | 4,310 | € 385 | 0 | € 0 | 0 | € 385 | € 64,000 | 166.3 |
| LI #12CO | Shut Off Outdoor Lighting In Daytime, Bldg 57 | 4 | 1,235 | € 110 | 0 | € 0 | 0 | € 110 | € 1,000 | 9.1 |
| LI #13CO | Add Skylights, Bldg 49 | 49 | 14,400 | € 1,286 | 0 | € 0 | 0 | € 1,286 | € 51,000 | 39.7 |
| LI #14US | Use Occupancy Sensors To Turn off Lights, Bldg 7951 and 7971 | 121 | 35,583 | € 3,178 | 0 | € 0 | 0 | € 3,178 | € 27,000 | 8.5 |
| LI #15US | Dim Lighting Using Daylighting Controls, Bldg 7988 | 154 | 45,108 | € 4,028 | 0 | € 0 | 0 | € 4,028 | € 14,400 | 3.6 |
| LI #16US | Install Skylight, Bldgs 7951 and 7988 | 454 | 132,987 | € 11,876 | 0 | € 0 | 0 | € 11,876 | € 141,588 | 11.9 |
| LI #17US | New Lighting System, Bldg 7902 | 382 | 112,000 | € 10,002 | 0 | € 0 | € 1,200 | € 11,202 | € 62,400 | 5.6 |
| LI #18US | New Lighting System, Bldg 7987, 7988 and 7989 | 1,730 | 507,000 | € 45,275 | 0 | € 0 | € 1,700 | € 46,975 | € 448,000 | 9.5 |
| LI #19US | New Light System Bldg 7971 | 149 | 43,750 | € 3,500 | 0 | € 0 | 0 | € 3,500 | € 17,100 | 4.9 |
| LI #20US | New Light System Bldg 7973 | 64 | 18,750 | € 1,500 | 0 | € 0 | 0 | € 1,500 | € 13,140 | 8.8 |
| LI #21US | New Light System Bldg 7974 | 115 | 33,750 | € 2,700 | 0 | € 0 | 0 | € 2,700 | € 13,140 | 4.9 |
| LI #22US | New Light System Bldg 7975 | 115 | 33,750 | € 2,700 | 0 | € 0 | 0 | € 2,700 | € 13,140 | 4.9 |
| LI #23US | New Light System Bldg 7976 | 149 | 43,750 | € 3,500 | 0 | € 0 | 0 | € 3,500 | € 17,100 | 4.9 |
| LI #24US | New Light System Bldg 7977-2 | 512 | 150,000 | € 12,000 | 0 | € 0 | 0 | € 12,000 | € 18,000 | 1.5 |
| LI #25US | New Light System Bldg 7977-3 | 512 | 137,500 | € 11,000 | 0 | € 0 | 0 | € 11,000 | € 16,500 | 1.5 |
| MUL #1 | Add Buildings to the UEMCS Building Control System | 0 | 0 | € 0 | 0 | € 0 | 0 | € 0 | 0 | 0 |
| MUL #2 | Re-commission Building Controls and HVAC systems | 0 | 0 | € 0 | 0 | € 0 | 0 | € 0 | 0 | 0 |

| ECM | ECM Description | Electricity Savings | | | Thermal | | Maintenance €/Yr | Total Savings: Electrical Use, Elec Demand, Thermal, and Maint €/Yr | Investment € | Simple Payback Years |
|---|---|---|---|---|---|---|---|---|---|---|
| | | MMBtu/Yr | KWh/yr | €/Yr | MMBtu/Yr | €/Yr | | | | |
| MUL #3 | LED Lighting Systems | 0 | 0 | € 0 | 0 | € 0 | 0 | € 0 | 0 | 0 |
| MUL #4 | Optimize Compressed Air Use and Compressor Size Bldg 7902 at Germersheim and Bldg 4 at Coleman Barracks | 0 | 175,000 | € 15,628 | 0 | 0 | 0 | € 15,628 | € 40,000 | 2.6 |
| MUL #5 | Replacement of Circulation Pumps | 0 | 0 | € 0 | 0 | € 0 | 0 | € 0 | 0 | 0 |
| MUL #6 | Switch off boilers, HW pumps, and Chillers Based On Outside Air Temperature Bldg 18 Campbell Barracks and Bldgs 49, 106 at Coleman Barracks | 205 | 60,000 | € 5,358 | 0 | € 0 | 0 | € 5,358 | 0 | 0.0 |
| RAD #1KS | Radiant Heating Katterbach Barracks Bldg 5801 | 0 | 0 | € 0 | 519 | € 12,768 | 0 | € 12,768 | € 103,000 | 8.1 |
| RAD #2KS | Radiant Heating Katterbach Barracks Bldg 5802 | 0 | 0 | € 0 | 440 | € 10,836 | 0 | € 10,836 | € 103,000 | 9.5 |
| RAD #3KS | Radiant Heating Katterbach Barracks Bldg 5806 | 0 | 0 | € 0 | 478 | € 11,760 | 0 | € 11,760 | € 190,000 | 16.2 |
| RAD #4KS | Radiant Heating Katterbach Barracks Bldg 5807 | 0 | 0 | € 0 | 1,270 | € 31,248 | 0 | € 31,248 | € 129,000 | 4.1 |
| RAD #5KS | Radiant Heating Storch Barracks Bldg 6500 | 0 | 0 | € 0 | 1,461 | € 35,952 | 0 | € 35,952 | € 268,000 | 7.5 |
| RAD #6KS | Radiant Heating Storch Barracks Bldg 6501 | 0 | 0 | € 0 | 1,239 | € 30,492 | 0 | € 30,492 | € 268,000 | 8.8 |
| RAD #7KS | Radiant Heating Storch Barracks Bldg 6502 | 0 | 0 | € 0 | 1,464 | € 36,036 | 0 | € 36,036 | € 268,000 | 7.4 |
| RAD #8KS | Radiant Heating Storch Barracks Bldg 6633 | 0 | 0 | € 0 | 457 | € 11,256 | 0 | € 11,256 | € 102,000 | 9.1 |
| REN #1CO | PV System Bldg 25 Coleman Barracks - Manheim | 268 | 78,595 | € 34,813 | | | | € 34,813 | € 368,881 | 10.6 |
| REN #2CO | PV System Bldg 11 Coleman Barracks - Manheim | 153 | 44,744 | € 20,107 | 0 | 0 | 0 | € 20,107 | € 201,297 | 10.0 |
| REN #3CO | PV System Bldg 13 Coleman Barracks - Manheim | 153 | 44,744 | € 20,107 | 0 | 0 | 0 | € 20,107 | € 201,297 | 10.0 |
| REN #4CO | PV System Bldg 15 Coleman Barracks - Manheim | 153 | 44,744 | € 20,107 | 0 | 0 | 0 | € 20,107 | € 201,297 | 10.0 |
| REN #5CO | PV System Bldg 17 Coleman Barracks - Manheim | 153 | 44,744 | € 20,107 | 0 | 0 | 0 | € 20,107 | € 201,297 | 10.0 |
| REN #6CO | PV System Bldg 29 Coleman Barracks - Manheim | 153 | 44,744 | € 20,107 | 0 | 0 | 0 | € 20,107 | € 201,297 | 10.0 |
| REN #7CO | PV System Bldg 31 Coleman Barracks - Manheim | 153 | 44,744 | € 20,107 | 0 | 0 | 0 | € 20,107 | € 201,297 | 10.0 |
| REN #8CO | PV System Bldg 33 Coleman Barracks - Manheim | 153 | 44,744 | € 20,107 | 0 | 0 | 0 | € 20,107 | € 201,297 | 10.0 |
| REN #9CO | PV System Bldg 35 Coleman Barracks - Manheim | 153 | 44,744 | € 20,107 | 0 | 0 | 0 | € 20,107 | € 201,297 | 10.0 |
| REN #10KS | PV System Bldg 9021 - Katterbach Barracks, Ansbach | 136 | 39,853 | € 17,720 | 0 | € 0 | 0 | € 17,720 | € 197,615 | 11.2 |
| REN #11KS | PV System Bldg 5810 - Katterbach Barracks, Ansbach | 183 | 53,650 | € 23,955 | 0 | € 0 | 0 | € 23,955 | € 248,848 | 10.4 |

| ECM | ECM Description | Electricity Savings | | | Thermal | | Maintenance €/Yr | Total Savings: Electrical Use, Elec Demand, Thermal, and Maint €/Yr | Investment € | Simple Payback Years |
|---|---|---|---|---|---|---|---|---|---|---|
| | | MMBtu/Yr | KWh/yr | €/Yr | MMBtu/Yr | €/Yr | | | | |
| REN #12KS | PV System Bldg 5819 - Katterbach Barracks, Ansbach | 178 | 52,123 | € 23,292 | 0 | € 0 | 0 | € 23,292 | € 241,529 | 10.4 |
| REN #13KS | PV System Open Space - Katterbach Barracks, Ansbach | 877 | 256,943 | € 111,469 | 0 | € 0 | 0 | € 111,469 | € 1,268,027 | 11.4 |
| REN #14KS | PV System Bldg 6629 – Storch Barracks, Illesheim | 286 | 83,925 | € 37,093 | 0 | € 0 | 0 | € 37,093 | € 395,229 | 10.7 |
| REN #15KS | PV System Bldg 6630 – Storch Barracks, Illesheim | 286 | 83,925 | € 37,093 | 0 | € 0 | 0 | € 37,093 | € 395,229 | 10.7 |
| REN #16KS | PV System Bldg 6608 – Storch Barracks, Illesheim | 203 | 59,533 | € 26,497 | 0 | € 0 | 0 | € 26,497 | € 285,443 | 10.8 |
| REN #17KS | PV System Bldg 6610 – Storch Barracks, Illesheim | 202 | 59,222 | € 26,350 | 0 | € 0 | 0 | € 26,350 | € 285,443 | 10.8 |
| REN #18KS | PV System Bldg 6612 – Storch Barracks, Illesheim | 201 | 59,023 | € 26,261 | 0 | € 0 | 0 | € 26,261 | € 285,443 | 10.9 |
| REN #19KS | PV System Bldg 6517 – Storch Barracks, Illesheim | 216 | 63,262 | € 28,148 | 0 | € 0 | 0 | € 28,148 | € 285,443 | 10.1 |
| REN #20KS | PV System Bldg 6633 – Storch Barracks, Illesheim | 68 | 20,070 | € 9,163 | 0 | € 0 | 0 | € 9,163 | € 96,804 | 10.6 |
| REN #21KS | PV System Open Space – Storch Barracks, Illesheim | 877 | 256,943 | € 111,469 | 0 | € 0 | 0 | € 111,469 | € 1,268,027 | 11.4 |
| REN #22US | Solar Wall, Bldgs 7950, 7951, 7954, 7955, 7971 and 7972 | 0 | 0 | € 0 | 1,113 | € 11,997 | 0 | € 11,997 | € 444,500 | 37.1 |
| REN #23US | Install a Wind Mill at Germersheim | 10,236 | 3,000,000 | € 267,900 | 0 | € 0 | -€ 45,000 | € 222,900 | € 2,000,000 | 9.0 |
| REN #24US | Photovoltaics Bldg 7889 - U.S. Depot Germersheim | 159 | 46,503 | € 20,843 | 0 | 0 | 0 | € 20,843 | € 218,208 | 10.5 |
| REN #25US | Photovoltaics Bldg 7823 - U.S. Depot Germersheim | 187 | 54,872 | € 24,481 | 0 | 0 | 0 | € 24,481 | € 265,167 | 10.8 |
| REN #26US | Photovoltaics Bldg 7834 - U.S. Depot Germersheim | 46 | 13,346 | € 6,135 | 0 | 0 | 0 | € 6,135 | € 64,534 | 10.5 |
| REN #27US | Photovoltaics Bldg 7846 - U.S. Depot Germersheim | 187 | 54,931 | € 24,508 | 0 | 0 | 0 | € 24,508 | € 256,167 | 10.5 |
| REN #28US | Photovoltaics Bldg 7826 - U.S. Depot Germersheim | 212 | 62,229 | € 27,688 | 0 | 0 | 0 | € 27,688 | € 285,443 | 10.3 |
| *Totals* | | *22,828* | *9,330,913* | *1,265,402* | *27,545* | *311,451* | *-1,738* | *1,717,752* | *14,833,544* | *8.6* |

Renewables, which have an aggregate payback of 11 years, should also be considered since funding opportunities such as the Energy Conservation Investment Program (ECIP), can give them special consideration regardless of their relatively long payback periods.

At **Campbell Barracks**, 10 ECMs were identified with simple paybacks ranging from immediate (modification of HVAC controls) to 30 years for an absorption chiller run from solar heat (Table 65). Obviously, implementation of the ECMs identified should be done only after considering the economic situation.

At **Coleman Barracks**, 28 ECMs were identified (Table 66). They would save 164 MWh/yr in electrical use and 821 MMBtu/yr in heating costs for a total of €40K savings per year. The investment cost of €151K results in a quick simple payback of 3.8 years.

At **Katterbach and Storch Barracks**, 20 ECMs were identified (Table 67) that would save 1,088 MWh/yr in electrical use and 723 MMBtu/yr in heating costs for a total of €659K savings per year. The investment cost of €6.7 million results in a relatively long payback of 10 years. While this is generally considered a relatively long payback period, the majority of the ECMs are renewable. Considering the emphasis on renewables and the likely increase in energy costs, these are attractive opportunities. Eight buildings were identified as having potential for radiant heating. The analysis includes a price quote from a local vendor and 30 percent design drawings.

At **U.S. Army Depot – Germersheim**, 23 ECMs were identified (Table 68). They would save 4,571 MWh/yr in electrical use and 1,686 MMBtu/yr in heating costs for a total of €463K savings per year. The investment cost of €4.4 million results in a relatively long payback of 9.5 years. While this is generally considered a relatively long payback period, many of them are renewable. Considering the emphasis on renewables and the likely increase in energy costs, these are attractive opportunities. Others such as new lighting systems in Bldg 7977 have very good payback period of 1.5 years.

For **Multiple Facilities**, six ECMs were identified that apply in general to all facilities. All were expected to have excellent paybacks.

Table 65. Summary of Campbell Barracks ECMs.

| ECM # | ECM Description | Electrical Savings KWh/yr | Electrical Savings €/Yr | Thermal MMBtu/Yr | Thermal €/Yr | Maintenance €/Yr | Total Savings: Electrical Use, Elec Demand, Thermal, and Maint €/Yr | Investment € | Simple Payback (yrs) |
|---|---|---|---|---|---|---|---|---|---|
| CEP #1CA | Analysis of the Secondary Heating System Pumps, Adjustment of the Size and Operation Mode | 2,700 | €241 | 0 | €0 | €0 | €241 | €2,500 | 10.4 |
| CEP #2CA | Additional Bio-Diesel-Fired Cogeneration Motor | 2,250,000 | €0 | 10239 | €0 | €28,362 | €171,000 | €449,000 | 15* |
| CEP #3CA | Optimization of the Central Cooling System | 0 | €0 | 314 | €26,900 | €0 | €26,900 | €343,000 | 12.8 |
| DIN #1CA | Utilize Kitchen Hood Control, Bldg 112 | 26,630 | €2,378 | 458 | €4,938 | €0 | €7,316 | €42,200 | 5.8 |
| HVAC #1CA | Repair Leaking Hot Water Valve, Bldg 18 | 157,000 | €14,020 | 1611 | €17,370 | €0 | €31,390 | €2,000 | 0.1 |
| HVAC #2CA | Adjust HVAC Unit Outdoor Air Using $CO_2$ sensors, Bldg 22 | 4,800 | €429 | 505 | €5,446 | €0 | €5,875 | €4,000 | 0.7 |
| HVAC #3CA | Modify Building Controls To Allow HVAC Unit Not Use 100% outside Air, Bldg 18 | 23,900 | €2,134 | 2536 | €27,342 | €0 | €29,477 | €1,000 | 0.0 |
| HVAC #4CA | Install Absorption Chiller Driven by Solar Collectors To Replace Electric Chiller - Bldg 3983 | 89,000 | €7,948 | 0 | €0 | €0 | €7,948 | €240,000 | 30.2 |
| LI #1CA | Use Occupancy Sensors To Turn off Lights | 1,272 | €114 | 0 | €0 | €0 | €114 | €1,100 | 9.7 |
| LI #2CA | Change Bulbs in Exit Lights | 17,520 | €1,565 | 0 | €0 | €2,400 | €3,965 | €18,000 | 4.5 |
| *Totals* | | *2,572,822* | *28,828* | *15,663* | *81,997* | *30,762* | *284,225* | *1,102,800* | *4* |

Table 66. Summary of Coleman Barracks ECMs.

| ECM # | ECM Description | Electrical Savings | | Thermal | | Maintenance €/Yr | Total Savings: Electrical Use, Elec Demand, Thermal, and Maint €/Yr | Investment € | Simple Payback Years |
|---|---|---|---|---|---|---|---|---|---|
| | | KWh/yr | €/Yr | MMBtu/Yr | €/Yr | | | | |
| BE #1CO | Install Panels in Areas Having Single Pane Windows, Bldg 25 | 0 | € 0 | 124 | € 1,336 | € 0 | € 1,336 | € 19,800 | 14.8 |
| BE #2CO | Reduce Door Size, Bldg 49 | 0 | € 0 | 290 | € 3,132 | € 0 | € 3,132 | € 44,500 | 14.2 |
| DIN #2CO | Modify Kitchen Hoods with End Skirts and Temperature Controlled Exhaust, Bldg 45 | 25,400 | € 3,629 | 240 | € 2,588 | € 0 | € 6,217 | € 40,600 | 6.5 |
| DIN #3CO | Use Low Flow Pre-rinse Kitchen Nozzles | 0 | € 0 | 146 | € 1,574 | € 0 | € 1,574 | € 80 | 0.1 |
| CEP #4CO | Substation Optimization – Coleman Barracks | 136,080 | € 27,216 | 0 | € 0 | € 0 | € 27,216 | € 45,000 | 1.7 |
| HVAC #5CO | Reduce Pressure and Recover Waste Heat from Air Compressor, Motor Pool Bldg 57 | 2,860 | € 255 | 20 | € 221 | € 0 | € 476 | € 1,000 | 2.1 |
| HVAC #6CO | Optimize the Use of Compressed Air and the Sizing of the Air Compressors – Hanger Bldg 4 | 130,000 | € 11,609 | 0 | € 0 | € 0 | € 11,609 | € 25,000 | 2.2 |
| HVAC #7CO | Replace Pneumatic Controls with DDC Bldg 4 | 0 | € 0 | 2048 | € 22,080 | € 0 | € 22,080 | € 150,000 | 6.8 |
| LI #3CO | Use Occupancy Sensors To Turn off Lights | 22,633 | € 2,021 | 0 | € 0 | € 0 | € 2,021 | € 11,500 | 5.7 |
| LI #4CO | Change Bulbs in Exit Lights | 34,950 | € 3,121 | 0 | € 0 | € 4,800 | € 7,921 | € 36,000 | 4.5 |
| LI #5CO | Reduce Lighting Using Day Lighting Controls, Band Lobby Area, Bldg 25 | 250 | € 22 | 0 | € 0 | € 0 | € 22 | € 400 | 17.9 |
| LI #6CO | Reduce Lighting Using Day Lighting Controls, Storage area Bldgs 49 | 4,310 | € 385 | 0 | € 0 | € 0 | € 385 | € 64,000 | 166.3 |
| LI #7CO | Shut Off Outdoor Lighting in Daytime, Bldg 57 | 1,235 | € 110 | 0 | € 0 | € 0 | € 110 | € 300 | 2.7 |
| LI #8CO | Add Skylights, Bldg 49 | 14,400 | € 1,286 | 0 | € 0 | € 0 | € 1,286 | € 51,000 | 39.7 |
| LI #9CO | Change Bulbs in Exit Lights | 34,950 | € 3,121 | 0 | € 0 | € 4,800 | € 7,921 | € 36,000 | 4.5 |
| LI #10CO | Reduce Lighting Using Day Lighting Controls, Band Lobby Area, Bldg 25 | 250 | € 22 | 0 | € 0 | € 0 | € 22 | € 400 | 17.9 |
| LI #11CO | Reduce Lighting Using Day Lighting Controls, Storage area Bldgs 49 | 4,310 | € 385 | 0 | € 0 | € 0 | € 385 | € 64,000 | 166.3 |
| LI #12CO | Shut Off Outdoor Lighting in Daytime, Bldg 57 | 1,235 | € 110 | 0 | € 0 | € 0 | € 110 | € 1,000 | 9.1 |
| LI #13CO | Add Skylights, Bldg 49 | 14,400 | € 1,286 | 0 | € 0 | € 0 | € 1,286 | € 51,000 | 39.7 |
| REN #1CO | PV System Bldg 25 Coleman Barracks - Manheim | 78,595 | € 34,813 | 0 | € 0 | € 0 | € 34,813 | € 368,881 | 10.6 |
| REN #2CO | PV System Bldg 11 Coleman Barracks - Manheim | 44,744 | € 20,107 | 0 | € 0 | € 0 | € 20,107 | € 201,297 | 10.0 |
| REN #3CO | PV System Bldg 13 Coleman Barracks - Manheim | 44,744 | € 20,107 | 0 | € 0 | € 0 | € 20,107 | € 201,297 | 10.0 |
| REN #4CO | PV System Bldg 15 Coleman Barracks - Manheim | 44,744 | € 20,107 | 0 | € 0 | € 0 | € 20,107 | € 201,297 | 10.0 |
| REN #5CO | PV System Bldg 17 Coleman Barracks - Manheim | 44,744 | € 20,107 | 0 | € 0 | € 0 | € 20,107 | € 201,297 | 10.0 |
| REN #6CO | PV System Bldg 29 Coleman Barracks - Manheim | 44,744 | € 20,107 | 0 | € 0 | € 0 | € 20,107 | € 201,297 | 10.0 |
| REN #7CO | PV System Bldg 31 Coleman Barracks - Manheim | 44,744 | € 20,107 | 0 | € 0 | € 0 | € 20,107 | € 201,297 | 10.0 |
| REN #8CO | PV System Bldg 33 Coleman Barracks - Manheim | 44,744 | € 20,107 | 0 | € 0 | € 0 | € 20,107 | € 201,297 | 10.0 |
| REN #9CO | PV System Bldg 35 Coleman Barracks - Manheim | 44,744 | € 20,107 | 0 | € 0 | € 0 | € 20,107 | € 201,297 | 10.0 |
| *Totals* | | *164,340* | *€ 31,101* | *821* | *€ 8,850* | *€ 0* | *€ 39,951* | *€ 150,980* | *3.8* |

Table 67. Summary of Katterbach and Storch Barracks ECMs.

| ECM # | ECM Description | Electrical Savings | | Thermal | | Maintenance €/Yr | Total Savings: Electrical Use, Elec Demand, Thermal, and Maint €/yr | Investment € | Simple Payback yrs |
|---|---|---|---|---|---|---|---|---|---|
| | | KWh/yr | €/Yr | MMBtu/Yr | €/Yr | | | | |
| RAD #1KS | Radiant Heating Katterbach Barracks Bldg 5801 | 0 | €0 | 519 | €12,768 | €0 | €12,768 | €103,000 | 8.1 |
| RAD #2KS | Radiant Heating Katterbach Barracks Bldg 5802 | 0 | €0 | 440 | €10,836 | €0 | €10,836 | €103,000 | 9.5 |
| RAD #3KS | Radiant Heating Katterbach Barracks Bldg 5806 | 0 | €0 | 478 | €11,760 | €0 | €11,760 | €190,000 | 16.2 |
| RAD #4KS | Radiant Heating Katterbach Barracks Bldg 5807 | 0 | €0 | 1270 | €31,248 | €0 | €31,248 | €129,000 | 4.1 |
| RAD #5KS | Radiant Heating Storch Barracks Bldg 6500 | 0 | €0 | 1461 | €35,952 | €0 | €35,952 | €268,000 | 7.5 |
| RAD #6KS | Radiant Heating Storch Barracks Bldg 6501 | 0 | €0 | 1239 | €30,492 | €0 | €30,492 | €268,000 | 8.8 |
| RAD #7KS | Radiant Heating Storch Barracks Bldg 6502 | 0 | €0 | 1464 | €36,036 | €0 | €36,036 | €268,000 | 7.4 |
| RAD #8KS | Radiant Heating Storch Barracks Bldg 6633 | 0 | €0 | 457 | €11,256 | €0 | €11,256 | €102,000 | 9.1 |
| REN #10KS | PV System Bldg 9021 – Katterbach Barracks, Ansbach | 39,853 | €17,720 | 0 | €0 | €0 | €17,720 | €197,615 | 11.2 |
| REN #11KS | PV System Bldg 5810 – Katterbach Barracks, Ansbach | 53,650 | €23,955 | 0 | €0 | €0 | €23,955 | €248,848 | 10.4 |
| REN #12KS | PV System Bldg 5819 – Katterbach Barracks, Ansbach | 52,123 | €23,292 | 0 | €0 | €0 | €23,292 | €241,529 | 10.4 |
| REN #13KS | PV System Open Space – Katterbach Barracks, Ansbach | 256,943 | €111,469 | 0 | €0 | €0 | €111,469 | €1,268,027 | 11.4 |
| REN #14KS | PV System Bldg 6629 – Storch Barracks, Illesheim | 83,925 | €37,093 | 0 | €0 | €0 | €37,093 | €395,229 | 10.7 |
| REN #15KS | PV System Bldg 6630 – Storch Barracks, Illesheim | 83,925 | €37,093 | 0 | €0 | €0 | €37,093 | €395,229 | 10.7 |
| REN #16KS | PV System Bldg 6608 – Storch Barracks, Illesheim | 59,533 | €26,497 | 0 | €0 | €0 | €26,497 | €285,443 | 10.8 |
| REN #17KS | PV System Bldg 6610 – Storch Barracks, Illesheim | 59,222 | €26,350 | 0 | €0 | €0 | €26,350 | €285,443 | 10.8 |
| REN #18KS | PV System Bldg 6612 – Storch Barracks, Illesheim | 59,023 | €26,261 | 0 | €0 | €0 | €26,261 | €285,443 | 10.9 |
| REN #19KS | PV System Bldg 6517 – Storch Barracks, Illesheim | 63,262 | €28,148 | 0 | €0 | €0 | €28,148 | €285,443 | 10.1 |
| REN #20KS | PV System Bldg 6633 – Storch Barracks, Illesheim | 20,070 | €9,163 | 0 | €0 | €0 | €9,163 | €96,804 | 10.6 |
| REN #21KS | PV System Open Space – Storch Barracks, Illesheim | 256,943 | €111,469 | 0 | €0 | €0 | €111,469 | €1,268,027 | 11.4 |
| *Totals* | | *1,088,472* | *€478,509* | *7328* | *€180,348* | *€0* | *€658,857* | *€6,684,080* | *10.1* |

Table 68. U.S. Army Depot – Germersheim ECMs.

| ECM # | ECM Description | Electrical Savings | | Thermal | | Maintenance €/yr | Total Savings: Electrical Use, Elec Demand, Thermal, and Maint (€/yr) | Investment € | Simple Payback yrs |
|---|---|---|---|---|---|---|---|---|---|
| | | KWh/yr | €/yr | MMBtu/yr | €/yr | | | | |
| BE #3US | Reduce Door Size Bldgs 7938 and 7941 | 0 | €0 | 232 | €2,499 | €0 | €2,499 | €30,300 | 12.1 |
| CEP #5US | Connection of the "Big O" Bldgs to the Central Heating System | 0 | €0 | 0 | €0 | €0 | €0 | €0 | 0.0 |
| HVAC #8US | Check Temperature Control and Check OA Damper Functions for Unit Heaters Bldg 7902 | 0 | €0 | 341 | €3,680 | €0 | €3,680 | €5,000 | 1.4 |
| HVAC #9US | Curt Optimize the Use of Compressed Air and the Sizing of the Air Compressors – Motor Pool Bldg 7902 Germersheim | 45,000 | €4,019 | 0 | €0 | €0 | €4,019 | €15,000 | 3.7 |
| LI #14US | Use Occupancy Sensors To Turn off Lights, Bldgs 7951 and 7971 | 35,583 | €3,178 | 0 | €0 | €0 | €3,178 | €27,000 | 8.5 |
| LI #15US | Dim Lighting Using Day Lighting Controls, Bldg 7988 | 45,108 | €4,028 | 0 | €0 | €0 | €4,028 | €14,400 | 3.6 |
| LI #16US | Install Skylight, Bldgs 7951 and 7988 | 132,987 | €11,876 | 0 | €0 | €0 | €11,876 | €141,588 | 11.9 |
| LI #17US | New Lighting System, Bldg 7902 | 112,000 | €10,002 | 0 | €0 | €1,200 | €11,202 | €62,400 | 5.6 |
| LI #18US | New Lighting System, Bldgs 7987, 7988, and7989 | 507,000 | €45,275 | 0 | €0 | €1,700 | €46,975 | €448,000 | 9.5 |
| LI #19US | New Light System Bldg 7971 | 43,750 | €3,500 | 0 | €0 | €0 | €3,500 | €17,100 | 4.9 |
| LI #20US | New Light System Bldg 7973 | 18,750 | €1,500 | 0 | €0 | €0 | €1,500 | €13,140 | 8.8 |
| LI #21US | New Light System Bldg 7974 | 33,750 | €2,700 | 0 | €0 | €0 | €2,700 | €13,140 | 4.9 |
| LI #22US | New Light System Bldg 7975 | 33,750 | €2,700 | 0 | €0 | €0 | €2,700 | €13,140 | 4.9 |
| LI #23US | New Light System Bldg 7976 | 43,750 | €3,500 | 0 | €0 | €0 | €3,500 | €17,100 | 4.9 |
| LI #24US | New Light System Bldg 7977-2 | 150,000 | €12,000 | 0 | €0 | €0 | €12,000 | €18,000 | 1.5 |
| LI #25US | New Light System Bldg 7977-3 | 137,500 | €11,000 | 0 | €0 | €0 | €11,000 | €16,500 | 1.5 |
| REN #22US | Solar Wall, Bldgs 7950, 7951, 7954, 7955, 7971, and 7972 | 0 | €0 | 1113 | €11,997 | €0 | €11,997 | €444,500 | 37.1 |
| REN #23US | Install a Wind Mill at Germersheim | 3,000,000 | €267,900 | 0 | €0 | -€45,000 | €222,900 | €2,000,000 | 9.0 |
| REN #24US | Photovoltaics Bldg 7889 - U.S. Depot Germersheim | 46,503 | €20,843 | 0 | €0 | €0 | €20,843 | €218,208 | 10.5 |
| REN #25US | Photovoltaics Bldg 7823 - U.S. Depot Germersheim | 54,872 | €24,481 | 0 | €0 | €0 | €24,481 | €265,167 | 10.8 |
| REN #26US | Photovoltaics Bldg 7834 - U.S. Depot Germersheim | 13,346 | €6,135 | 0 | €0 | €0 | €6,135 | €64,534 | 10.5 |
| REN #27US | Photovoltaics Bldg 7846 - U.S. Depot Germersheim | 54,931 | €24,508 | 0 | €0 | €0 | €24,508 | €256,167 | 10.5 |
| REN #28US | Photovoltaics Bldg 7826 - U.S. Depot Germersheim | 62,229 | €27,688 | 0 | €0 | €0 | €27,688 | €285,443 | 10.3 |
| *Totals* | | *4,570,809* | *€486,830* | *1686* | *€18,176* | *-€42,100* | *€462,906* | *€4,385,827* | *9.5* |

The Level I analyses of multiple complex systems conducted during the Energy Optimization Assessment are not intended to be (nor should they be) precise. The quantity and quality of the systems improvements identified suggests that significant potential exists.

## Recommendations

ECMs that apply to all facilities (Table 69, also labeled “Multiple” in Table 64), Central Energy Plants, Dining Facilities, and HVAC should be pursued. All had aggregate paybacks of less than 6 years. Renewables, which have an aggregate payback of 11 years, should also be pursued since there are funding opportunities such as ECIP, which give them special consideration without regard for their relatively long payback periods.

### Central energy plants

The central energy plants were found to be in very good condition. The best project was found to be the optimization of the substation pumping. At Coleman Barracks, this could save €27K per year. An investment of €45K results in a simple payback of 1.7 years. It is recommended that this be pursued with either internal funds or other funds that become available.

### Low to moderate cost projects

The 18 ECMs summarized in Table 70 were found to have an investment of €20K or less and result in a simple payback of 6 years or less. All could be implemented for a total of €167K, save €127K/yr, and result in a simple payback of just over 1.2 years. Internal funding for these projects should be sought.

### Good payback and moderate investment projects

Table 71 lists 10 ECMs that simple paybacks of less than 10 years, but that require moderate investments of between €20K and €200K. These ECMs together would have annual savings of €134K at a cost of €627K for a simple payback of 4.7 years.

### Good payback and significant investment projects

Nineteen ECMs were found to have significant investment requirements (over €200K) and payback periods of 10 years of less (Table 72). The majority of them are renewable. Renewable projects with a quick a payback are difficult to find. It is recommended that they be pursued aggressively. The ECIP program is particularly well suited to these larger renewable energy projects.

Table 69.  Summary of ECMs that apply to multiple facilities.

| ECM # | ECM Description | Electrical Savings KWh/yr | Electrical Savings €/yr | Thermal MMBtu/yr | Thermal €/yr | Maintenance €/yr | Total Savings: Electrical Use, Elec Demand, Thermal, and Maint (€/yr) | Investment € | Simple Payback yrs |
|---|---|---|---|---|---|---|---|---|---|
| MUL #1* | Add Buildings to the UEMCS Building Control System | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - |
| MUL #2* | Re-Commission Building Controls and HVAC systems | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MUL #3* | LED Lighting Systems | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - |
| MUL #4 | Optimize Compressed Air Use and Compressor Size Bldg 7902 at Germersheim and Bldg 4 at Coleman Barracks | 175,000 | 15,628 | 0 | 0 | 0 | 15,628 | 40,000 | 3 |
| MUL #5* | Replacement of Circulation Pumps | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - |
| MUL #6 | Switch Off Boilers, HW Pumps, and Chillers Based on Outside Air Temperature Bldg 18 Campbell Barracks and Bldgs 49 and 106 at Coleman Barracks | 60,000 | 5,358 | 0 | 0 | 0 | 5,358 | 0 | 0 |
| *Totals* | | *235,000* | *€20,986* | *0* | *€0* | *€0* | *€20,986* | *€40,000* | *1.9* |
| *Note: MUL #1, MUL #2, MUL #3, and MUL #5 were not evaluated economically due to a lack of available information., | | | | | | | | | |

Table 70. ECMs with investment < €20K and simple payback < 6 yrs.

| ECM# | ECM Description | Electrical Savings | | Thermal | | Maintenance | Total Savings: Electrical Use, Elec Demand, Thermal, and Maint (€/Yr) | Investment € | Simple Payback yrs |
|---|---|---|---|---|---|---|---|---|---|
| | | KWh/yr | €/Yr | MMBtu/Yr | €/Yr | €/Yr | | | |
| MUL #6 | Switch Off Boilers, HW Pumps, and Chillers Based on Outside Air Temperature Bldg 18 Campbell Barracks and Bldgs 49 and 106 at Coleman Barracks | 60,000 | 5,358 | 0 | 0 | 0 | 5,358 | 0 | 0 |
| DIN #3CO | Use Low Flow Pre-rinse Kitchen Nozzles | 0 | 0 | 146 | 1,574 | 0 | 1,574 | 80 | 0 |
| LI #25US | New Light System Bldg 7977-3 | 137,500 | 11,000 | 0 | 0 | 0 | 11,000 | 16,500 | 2 |
| HVAC #1CA | Repair Leaking Hot Water Valve, Bldg 18 | 157,000 | 14,020 | 1,611 | 17,370 | 0 | 31,390 | 2,000 | 0 |
| HVAC #2CA | Adjust HVAC Unit Outdoor Air Using $CO_2$ sensors, Bldg 22 | 4,800 | 429 | 505 | 5,446 | 0 | 5,875 | 4,000 | 1 |
| HVAC #3CA | Modify Building Controls To Allow HVAC Unit Not Use 100% outside Air, Bldg 18 | 23,900 | 2,134 | 2,536 | 27,342 | 0 | 29,477 | 1,000 | 0 |
| HVAC #5CO | Reduce Pressure and Recover Waste Heat from Air Compressor, Motor Pool Bldg 57 | 2,860 | 255 | 20 | 221 | 0 | 476 | 1,000 | 2 |
| HVAC #8US | Check Temperature Control and Check OA Damper Functions for Unit Heaters Bldg 7902 | 0 | 0 | 341 | 3,680 | 0 | 3,680 | 5,000 | 1 |
| HVAC #9US | Optimize Use of Compressed Air and Sizing of the Air Compressors – Motor Pool Bldg 7902 Germersheim | 45,000 | 4,019 | 0 | 0 | 0 | 4,019 | 15,000 | 4 |
| LI #2CA | Change Bulbs in Exit Lights | 17,520 | 1,565 | 0 | 0 | 2,400 | 3,965 | 18,000 | 5 |
| LI #3CO | Use Occupancy Sensors to Turn off Lights | 22,633 | 2,021 | 0 | 0 | 0 | 2,021 | 11,500 | 6 |
| LI #7CO | Shut off Outdoor Lighting in Daytime, Bldg 57 | 1,235 | 110 | 0 | 0 | 0 | 110 | 300 | 3 |
| LI #24US | New Light System Bldg 7977-2 | 150,000 | 12,000 | 0 | 0 | 0 | 12,000 | 18,000 | 2 |
| LI #15US | Dim Lighting Using Day Lighting Controls, Bldg 7988 | 45,108 | 4,028 | 0 | 0 | 0 | 4,028 | 14,400 | 4 |
| LI #21US | New Light System Bldg 7974 | 33,750 | 2,700 | 0 | 0 | 0 | 2,700 | 13,140 | 5 |
| LI #22US | New Light System Bldg 7975 | 33,750 | 2,700 | 0 | 0 | 0 | 2,700 | 13,140 | 5 |
| LI #19US | New Light System Bldg 7971 | 43,750 | 3,500 | 0 | 0 | 0 | 3,500 | 17,100 | 5 |
| LI #23US | New Light System Bldg 7976 | 43,750 | 3,500 | 0 | 0 | 0 | 3,500 | 17,100 | 5 |
| *Totals* | | *822,556* | *69,339* | *5,159* | *55,633* | *2,400* | *127,373* | *167,260* | *2.6* |

Table 71. ECMs with investments between €20K and €200K and simple payback of less than 10 years.

| ECM # | ECM Description | Electrical Savings | | Thermal | | Maintenance €/Yr | Total Savings: Electrical Use, Elec Demand, Thermal, and Maint €/Yr | Investment € | Simple Payback yrs |
|---|---|---|---|---|---|---|---|---|---|
| | | KWh/yr | €/Yr | MMBtu/Yr | €/Yr | | | | |
| CEP #4CO | Substation Optimization - Coleman Barracks | 136,080 | 27,216 | 0 | 0 | 0 | 27,216 | 45,000 | 2 |
| MUL #4 | Optimize Compressed Air Use and Compressor Size Bldg 7902 at Germersheim and Bldg 4 at Coleman Barracks | 175,000 | 15,628 | 0 | 0 | 0 | 15,628 | 40,000 | 3 |
| RAD #4KS | Radiant Heating Katterbach Barracks Bldg 5807 | 0 | 0 | 1,270 | 31,248 | 0 | 31,248 | 129,000 | 4 |
| LI #9CO | Change Bulbs in Exit Lights | 34,950 | 3,121 | 0 | 0 | 4,800 | 7,921 | 36,000 | 5 |
| LI #17US | New Lighting System, Bldg 7902 | 112,000 | 10,002 | 0 | 0 | 1,200 | 11,202 | 62,400 | 6 |
| DIN #1CA | Utilize Kitchen Hood Control, Bldg 112 | 26,630 | 2,378 | 458 | 4,938 | 0 | 7,316 | 42,200 | 6 |
| DIN #2CO | Modify Kitchen Hoods with End Skirts and Temperature Controlled Exhaust, Bldg 45 | 25,400 | 3,629 | 240 | 2,588 | 0 | 6,217 | 40,600 | 7 |
| RAD #1KS | Radiant Heating Katterbach Barracks, Bldg 5801 | 0 | 0 | 519 | 12,768 | 0 | 12,768 | 103,000 | 8 |
| LI #14US | Use Occupancy Sensors To Turn Off Lights, Bldg 7951 and 7971 | 35,583 | 3,178 | 0 | 0 | 0 | 3,178 | 27,000 | 8 |
| RAD #8KS | Radiant Heating Storch Barracks Bldg 6633 | 0 | 0 | 457 | 11,256 | 0 | 11,256 | 102,000 | 9 |
| *Totals* | | *545,643* | *65,151* | *2,944* | *62,798* | *6,000* | *133,949* | *627,200* | *4.7* |

Table 72. ECMs requiring investment > $200K and simple payback <= 10 years.

| ECM # | ECM Description | Electrical Savings | | Thermal | | Maintenance €/yr | Total Savings: Electrical Use, Elec Demand, Thermal, and Maint €/yr | Investment € | Simple Payback yrs |
|---|---|---|---|---|---|---|---|---|---|
| | | KWh/yr | €/yr | MMBtu/yr | €/yr | | | | |
| RAD #7KS | Radiant Heating Storch Barracks Bldg 6502 | 0 | 0 | 1,464 | 36,036 | 0 | 36,036 | 268,000 | 7 |
| RAD #5KS | Radiant Heating Storch Barracks Bldg 6500 | 0 | 0 | 1,461 | 35,952 | 0 | 35,952 | 268,000 | 7 |
| RAD #6KS | Radiant Heating Storch Barracks Bldg 6501 | 0 | 0 | 1,239 | 30,492 | 0 | 30,492 | 268,000 | 9 |
| REN #23US | Install a Wind Mill at Germersheim | 3,000,000 | 267,900 | 0 | 0 | -45,000 | 222,900 | 2,000,000 | 9 |
| LI #18US | New Lighting System, Bldgs 7987, 7988, and7989 | 507,000 | 45,275 | 0 | 0 | 1,700 | 46,975 | 448,000 | 10 |
| REN #2CO | PV System Bldg 11 Coleman Barracks - Manheim | 44,744 | 20,107 | 0 | 0 | 0 | 20,107 | 201,297 | 10 |
| REN #3CO | PV System Bldg 13 Coleman Barracks - Manheim | 44,744 | 20,107 | 0 | 0 | 0 | 20,107 | 201,297 | 10 |
| REN #4CO | PV System Bldg 15 Coleman Barracks - Manheim | 44,744 | 20,107 | 0 | 0 | 0 | 20,107 | 201,297 | 10 |
| REN #5CO | PV System Bldg 17 Coleman Barracks - Manheim | 44,744 | 20,107 | 0 | 0 | 0 | 20,107 | 201,297 | 10 |
| REN #6CO | PV System Bldg 29 Coleman Barracks - Manheim | 44,744 | 20,107 | 0 | 0 | 0 | 20,107 | 201,297 | 10 |
| REN #7CO | PV System Bldg 31 Coleman Barracks - Manheim | 44,744 | 20,107 | 0 | 0 | 0 | 20,107 | 201,297 | 10 |
| REN #8CO | PV System Bldg 33 Coleman Barracks - Manheim | 44,744 | 20,107 | 0 | 0 | 0 | 20,107 | 201,297 | 10 |
| REN #9CO | PV System Bldg 35 Coleman Barracks - Manheim | 44,744 | 20,107 | 0 | 0 | 0 | 20,107 | 201,297 | 10 |
| REN #19KS | PV System Bldg 6517 – Storch Barracks, Illesheim | 63,262 | 28,148 | 0 | 0 | 0 | 28,148 | 285,443 | 10 |
| REN #28US | Photovoltaics Bldg 7826 - U.S. Depot Germersheim | 62,229 | 27,688 | 0 | 0 | 0 | 27,688 | 285,443 | 10 |
| REN #12KS | PV System Bldg 5819 - Katterbach Barracks, Ansbach | 52,123 | 23,292 | 0 | 0 | 0 | 23,292 | 241,529 | 10 |
| REN #11KS | PV System Bldg 5810 - Katterbach Barracks, Ansbach | 53,650 | 23,955 | 0 | 0 | 0 | 23,955 | 248,848 | 10 |
| REN #27US | Photovoltaics Bldg 7846 - U.S. Depot Germersheim | 54,931 | 24,508 | 0 | 0 | 0 | 24,508 | 256,167 | 10 |
| REN #24US | Photovoltaics Bldg 7889 - U.S. Depot Germersheim | 46,503 | 20,843 | 0 | 0 | 0 | 20,843 | 218,208 | 10 |
| *Totals* | | *4,197,650* | *622,465* | *4,164* | *102,480* | *-43,300* | *681,645* | *6,398,014* | *9.4* |

### Level II analysis candidates

The installation of a windmill at the U.S. Army Depot in Germersheim is estimated to have a payback of 9 years, which is very good for a renewable. However this ECM was not studied in detail as others such as the photovoltaics and radiant heating. It is therefore recommended that a Level II analysis be performed on this ECM.

## Lessons learned

An EPOA is a complex undertaking. There are several key elements that require significant attention to guarantee success:

1. The involvement of key facility personnel who know what the problems are, where they are, and who have thought of many solutions
2. The facility personnel's sense of "ownership" of the ideas, which in turn develops a commitment for implementation
3. The EPOA focus on site-specific, critical cost issues, which, if solved, will make the greatest possible economic contribution to the installation's facility's bottom-line.

Major cost issues are:

- facility utilization (bottlenecks)
- maintenance and repair optimization (off spec, scrap, rework)
- labor (productivity, planning/scheduling)
- energy (steam, electricity, compressed air)
- waste (air, water, solid, hazardous)
- equipment (outdated or state-of-the-art), etc.

From a cost perspective, facility capacity, materials, and labor utilization are far more significant than energy and environmental concerns. However, all of these issues must be considered together to achieve DOD's mission of military readiness in the most efficient, cost-effective way. The Energy Assessment Protocol developed by CERL in collaboration with a number of government, institutional, and private sector parties is based on the analysis of the information available from literature, training materials, documented and undocumented practical experiences of contributors, and successful showcase energy assessments conducted by a diverse team of experts at the U.S. Army facilities. The protocol addresses both technical and nontechnical, organizational capabilities required to conduct a successful assessment geared to identifying measures that can reduce energy and other operating costs without adversely impacting product quality, safety, morale, or the environment.

Expertise in energy auditing is not an isolated set of skills, methods, or procedures; it requires a combination of skills and procedures from different fields. However, an energy and process audit requires a specific talent for putting together existing ways and procedures to show the overall energy performance of a building and the processes it houses, and how the energy performance of that building can be improved. A well grounded energy and process audit team should have expertise in the fields of HVAC, structural engineering, electrical and automation engineering; they should also have a good understanding of production processes.

Most of the knowledge necessary for an energy audit is a part of already existing expertise. Designers, consultants, contractors, and material and equipment suppliers should be familiar with the energy performance of the specific field in which they are experts. Structural designers and consultants should be familiar with heat losses through the building shell and what insulation should be added. Heating and ventilation engineers should be familiar with the energy performance of heating, ventilation, compressed air, and heat recovery systems. Designers of electrical systems should know energy performance of different motors, VFD drives and lighting systems. An industrial process and energy audit requires knowledge of process engineers specialized in certain processes.

Critical to any energy and process audit team member is the ability to apply a “holistic” approach to the energy sources and sinks in the audited target (installation, building, system, or their elements), and the ability to “step outside the box.” This ability presumes a thorough understanding of the processes performed in the audited building, and of the needs of the end users. For this reason, the end users themselves are important members of the team. It is critical for management, production, operations and maintenance (O&M) staff, energy managers, and on-site contractors to “buy in” to the implementation by participating in the process, sharing their knowledge and expertise, gathering information, and developing ideas.

# Acronyms and Abbreviations

| Term | Spellout |
|---|---|
| ACSIM | Assistant Chief of Staff for Installation Management |
| AHU | air handling unit |
| ASHRAE | American Society of Heating, Refrigerating, and Air-Conditioning Engineers |
| BE | Building Envelope |
| BIMA | Bundesvermögensamt |
| BP | British Petroleum |
| BSB | Base Support Battalion |
| BTU | British Thermal Unit |
| CDD | cooling degree days |
| CEERD | U.S. Army Corps of Engineers, Engineer Research and Development Center |
| CEP | Central Energy Plant |
| CERL | Construction Engineering Research Laboratory |
| CFM | cubic feet per minute |
| CIS | copper indium diselenide (CIS) |
| CO | Coleman Barracks |
| COP | coefficient of performance |
| COR | Contract Officer Representative |
| DAT | dual axis tracking |
| DDC | direct digital control |
| DDDE | Defense Distribution Depot Europe |
| DIN | Dining Facility |
| DPW | Directorate of Public Works |
| ECBCS | Energy Conservation in Buildings and Community Systems |
| ECM | Energy Conservation Measure |
| EEAP | Engineering Energy Analysis Program |
| EMCS | Energy Management Control System |
| EPAct | Energy Policy Act |
| EPOA | Energy and Process Optimization Assessment |
| ERDC | Engineer Research and Development Center |
| ESPC | Energy Savings Performance Contract |
| FPM | feet/minute |
| FY | fiscal year |
| gpm | gallons per minute |
| HDD | heating degree days |
| hp | horsepower |
| HQ | headquarters |

| Term | Spellout |
|---|---|
| HQIMCOM | Headquarters, Installation Management Command |
| HVAC | heating, ventilating, and air-conditioning |
| HW | hot water |
| IEA | International Energy Agency |
| IMA | Installation Management Agency |
| IMCOM | Installation Management Command |
| KW | kilowatt |
| KWH | kilowatt hour |
| LED | light emitting diode |
| LI | Lighting |
| MMBTU | 1 million BTUs |
| MUL | Multiple Facilities |
| MW | megawatt |
| MWH | megawatt hour |
| NATO | North Atlantic Treaty Organization |
| NL | Netherlands |
| OA | outdoor air |
| psi | pounds per square inch (psi) |
| PV | photovoltaic |
| RA | return air |
| RAD | Radiant Heating |
| REN | Renewables |
| SAT | single axis tracking |
| SF | square feet |
| TR | Technical Report |
| UEMCS | Utility Energy Monitoring and Control System |
| UEPH | Unaccompanied Enlisted Personnel Housing |
| UMCS | Utility Monitoring and Control System |
| USAG | U.S. Army Garrison |
| USAREUR | U.S. Army, Europe |
| VAV | variable air volume |
| VFD | variable frequency drive |
| WWW | World Wide Web |

# Appendix A: Solar domestic Hot Water Potential

Energy Assessment Report Solar Systems (Domestic Hot Water)
Solar Systems Standard Solutions (1000 L/2000 L)
Appropriate Buildings for Solar Systems

- Heidelberg
- Mannheim
- Schinnen

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# Preface

## Irradiation Ratios

Figure A1 shows the differences between the irradiation intensity in the five locations (Chievres, Schinnen, Ansbach, Mannheim/ Heidelberg/ Germersheim, and Vicenza) and Berlin.

The Standard Solar Systems are designed with the climate data of Berlin.

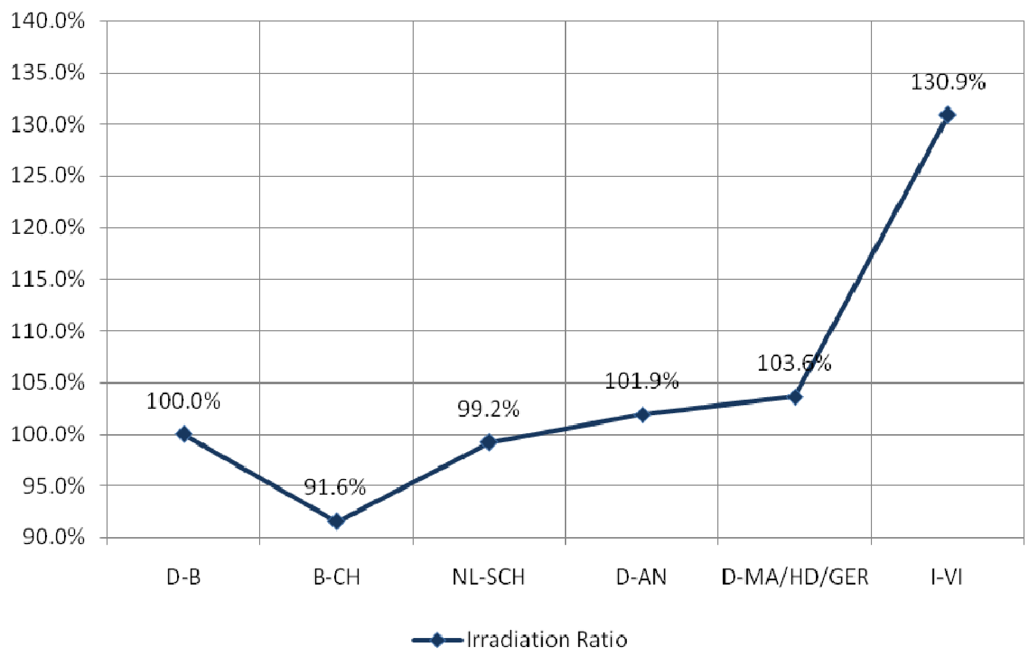



Figure A1. Irradiation ratio – country.

The irradiation in Chievres is on a lower level, the irradiation in Schinnen, Ansbach, Mannheim, Heidelberg, Germersheim are about on an equal level and the irradiation in Vicenza is on a significantly higher level than the irradiation in Berlin.

Table A1. Irradiation ratio – country and system area.

| Irradiation | Berlin | Chievres | Schinnen | Ansbach | MA/HD/GER | Vicenza |
|---|---|---|---|---|---|---|
| Solar System Area 10.6 m² | 11.413 | 10.451 | 11.320 | 11.628 | 11.827 | 14.940 |
| Irradiation Ratio (Country) | 100.0% | 91.6% | 99.2% | 101.9% | 103.6% | 130.9% |
| Solar System Area 17.1 m² | 19.783 | 18.114 | 19.622 | 20.155 | 20.501 | 25.896 |
| Irradiation Ratio (Country) | 100.0% | 91.6% | 99.2% | 101.9% | 103.6% | 130.9% |

In Table A1 the irradiation values and the irradiation ratio are shown per country and per Solar System size:

- 1.000 L/day – System/10.6 m² collector area
- 2.000 L/day – System/17.1 m² collector area.

The results of Table A1 (see also Tables A2 and A3) clarify that it might be a problem to install economic efficient Solar Systems in the Northern parts of Europe.

## Coverage and Efficiency

Both Standard Solar Systems are designed to cover in summertime (Mai – September) most/all domestic hot water requirements.

The Solar Systems deliver hot water with a temperature of 45 °C. The minimum temperature of the cold water supply is at 10 °C

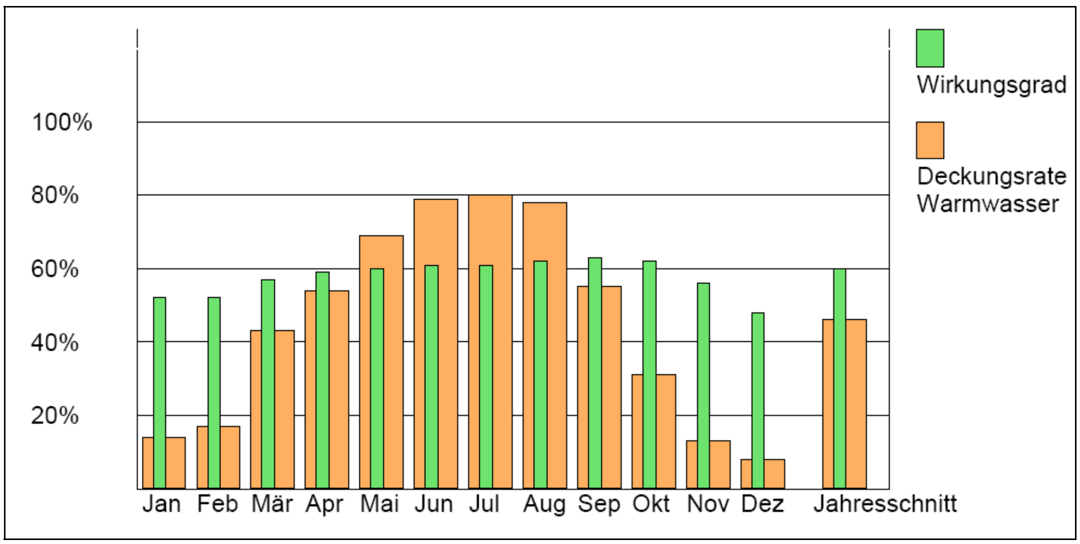



Figure A2. Solar system (1.000 L/day ) coverage and efficiency.

The efficiency factor of this Solar System is 60.

The total coverage per year is shown in Table A2.

Table A2. Total coverage per year/1.000 L/day solar system.

| Coverage (1.000 L/day) | Berlin | Chievres | Schinnen | Ansbach | MA/HD/GER | Vicenza |
|---|---|---|---|---|---|---|
| Total Energy Requirement (kWh) | 14.580 | 14.580 | 14.580 | 14.580 | 14.580 | 14.580 |
| Solar Energy Production (kWh) | 6.880 | 6.300 | 6.824 | 7.010 | 7.130 | 9.006 |
| Coverage/yr (%) | 47% | 43% | 47% | 48% | 49% | 62% |

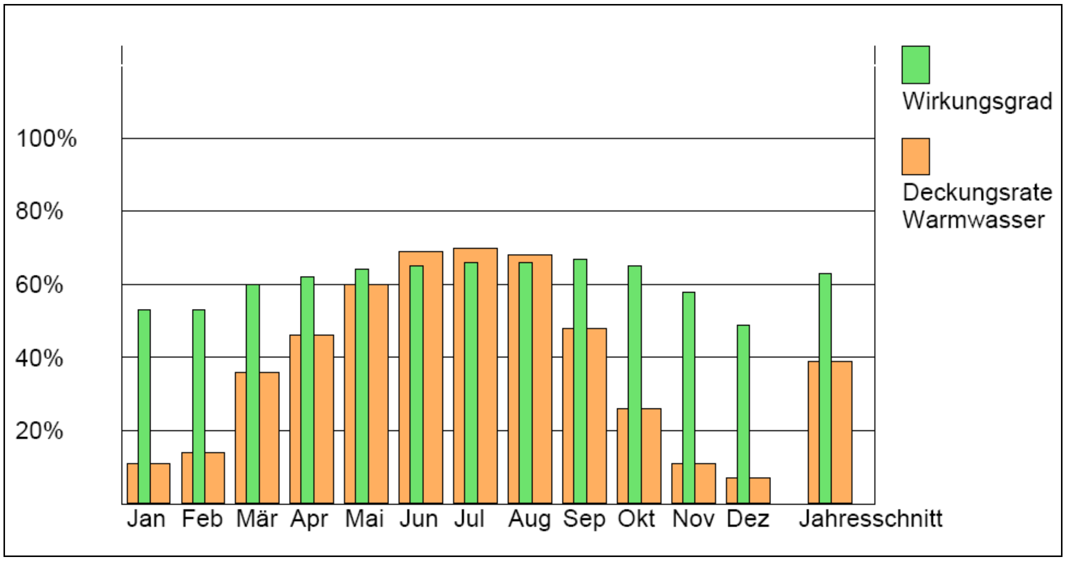



Figure A3. Solar system (2.000 L/day) coverage and efficiency.

The efficiency factor of this Solar System is 63.

The total coverage per year is shown in Table A3.

Table A3. Total coverage per year/2.000 L/day solar system.

| Coverage (2.000 L/day) | Berlin | Chievres | Schinnen | Ansbach | MA/HD/GER | Vicenza |
|---|---|---|---|---|---|---|
| Total Energy Requirement (kWh) | 29.160 | 29.160 | 29.160 | 29.160 | 29.160 | 29.160 |
| Solar Energy Production (kWh) | 12.368 | 11.325 | 12.267 | 12.601 | 12.816 | 16.190 |
| Coverage/yr (%) | 42% | 39% | 42% | 43% | 44% | 56% |

### Basic Calculation Values

Table A4. Basic calculation values.

| | | | |
|---|---|---|---|
| Fuel Oil/Natural Gas Price (€/kWh) | 0,080 | Basic Prices Solar System (€/m²) | |
| District Heat Price (€/kWh) | 0,100 | 1.000 L/Day - System | 1.549 |
| Price Increase Energy | 3% | 2.000 L/Day - System | 1.162 |
| Calculation Period (years) | 20 | 3.000 L/Day - System | 906 |
| Capital Costs | Not considered | 4.000 L/Day - System | 794 |
| Installation Costs | Included | 5.000 L/Day - System | 739 |

The orientation quotations from ELCO include the 1.000 and 2.000 L/day Solar Systems. The basic prices for the 3.000 – 5.000 L/day Solar Systems are extrapolated based on the orientation quotation.

All investment prices and calculation results are orientation values partially based on the ELCO quotation or on assumptions derived from information of the energy assessments. The fuel oil and the natural gas prices are expected to be at the same level at average.

The objective of the study is to show those cases for which it is worthwhile to design a Solar System for a specific building or application, and the amortization times that may than be expected.

All Solar Systems are designed with tube collectors, the most efficient, but also the most expensive technology. The given prices from ELCO seem to be on the very upper end.

Therefore a version with a 25 percent investment decrease is shown in the calculations as well. It can be assumed that in case of realization the investment prices will be lower because of a dedicated design and because of the purchasing negotiations.

## Economic Efficiency – Standard Solar Systems

### Economic Efficiency – Fuel Oil/Natural Gas – 1.000 L

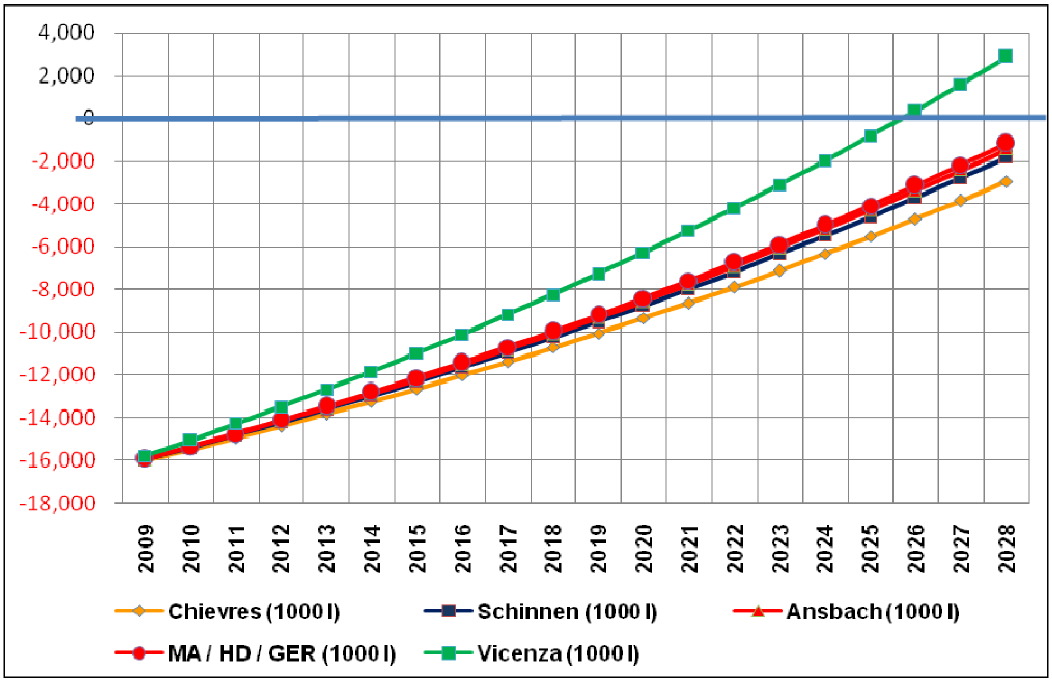



Figure A4. Economic efficiency of 1.000 L/day solar system (fuel oil/natural gas).

Table A5. Economic efficiency 1.000 L/day solar system (fuel oil/natural gas).

| Location | Chievres | Schinnen | Ansbach | MA/HD/GER | Vicenza |
|---|---|---|---|---|---|
| Investment (€) | 16.500 | 16.500 | 16.500 | 16.500 | 16.500 |
| Energy Savings/first year (€) | 504 | 546 | 561 | 570 | 721 |
| Amortization period without capital costs (years) | > 20 | > 20 | > 20 | > 20 | 17 |

A Solar System with this capacity substituting a fuel oil/natural gas boiler is not recommended for any location. If the investment price will be significantly lower it might get certain economic efficiency in Vicenza, but not in the other locations.

**Economic Efficiency – Fuel Oil/Natural Gas – 2.000 L**

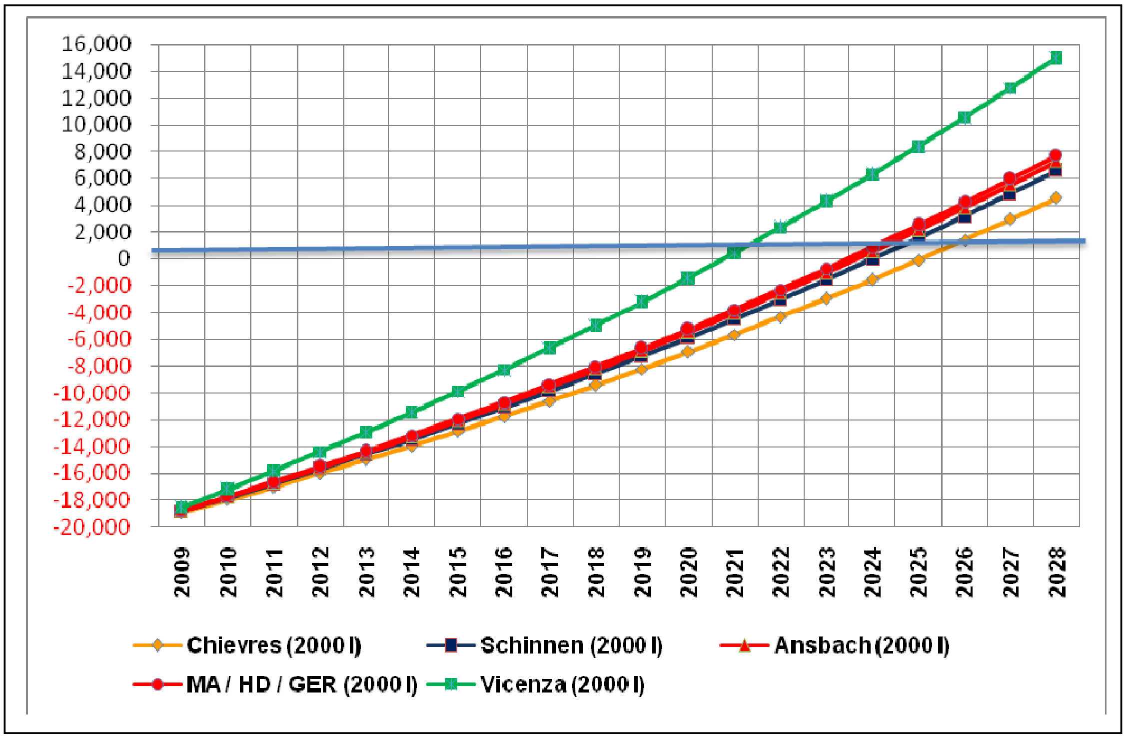



Figure A5. Economic efficiency 2.000 L/day solar system (fuel oil/natural gas).

Table A6. Economic efficiency 2.000 L/day solar system (fuel oil/natural gas).

| Location | Chievres | Schinnen | Ansbach | MA/HD/GER | Vicenza |
|---|---|---|---|---|---|
| Investment (€) | 19.800 | 19.800 | 19.800 | 19.800 | 19.800 |
| Energy Savings/first year (€) | 906 | 981 | 1.008 | 1.025 | 1.295 |
| Amortization period without capital costs (years) | 17 | 16 | 15 | 15 | 12 |

A Solar System with this capacity substituting a fuel oil/natural gas boiler is not recommended for the Northern locations in Europe. With the basic investment price certain economic efficiency in Vicenza is expected. The situation will improve if the investment price will be significantly lower as the following Figure A6 and Table A7 show.

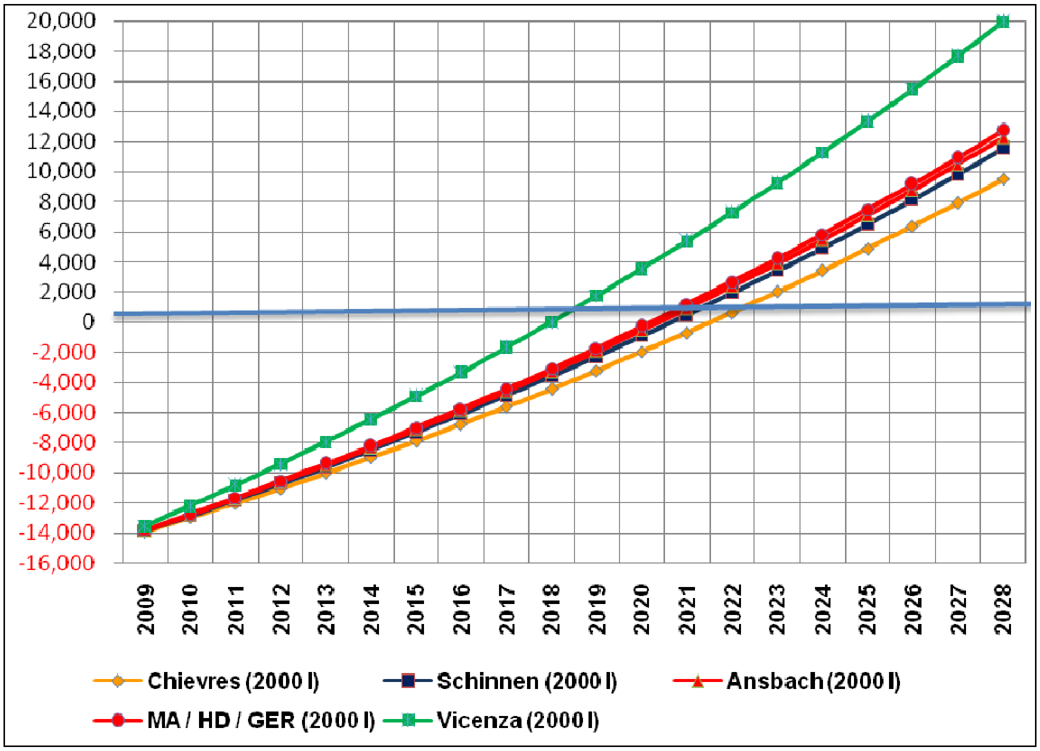



Figure A6. Economic efficiency 2.000 L/day solar system, fuel oil/natural gas (-25% invest)

Table A7. Economic efficiency 2.000 L/day solar system (fuel oil/natural gas) (-25% invest).

| Location | Chievres | Schinnen | Ansbach | MA/HD/GER | Vicenza |
|---|---|---|---|---|---|
| Investment (€) | 14.850 | 14.850 | 14.850 | 14.850 | 14.850 |
| Energy Savings/first year (€) | 906 | 981 | 1.008 | 1.025 | 1.295 |
| Amortization period without capital costs (years) | 13 | 12 | 12 | 12 | 10 |

If the investment price will be decreased by 25 percent the economic efficiency will tend to an acceptable level in all locations except Chievres.

## Economic Efficiency – District Heat – 1.000 L.

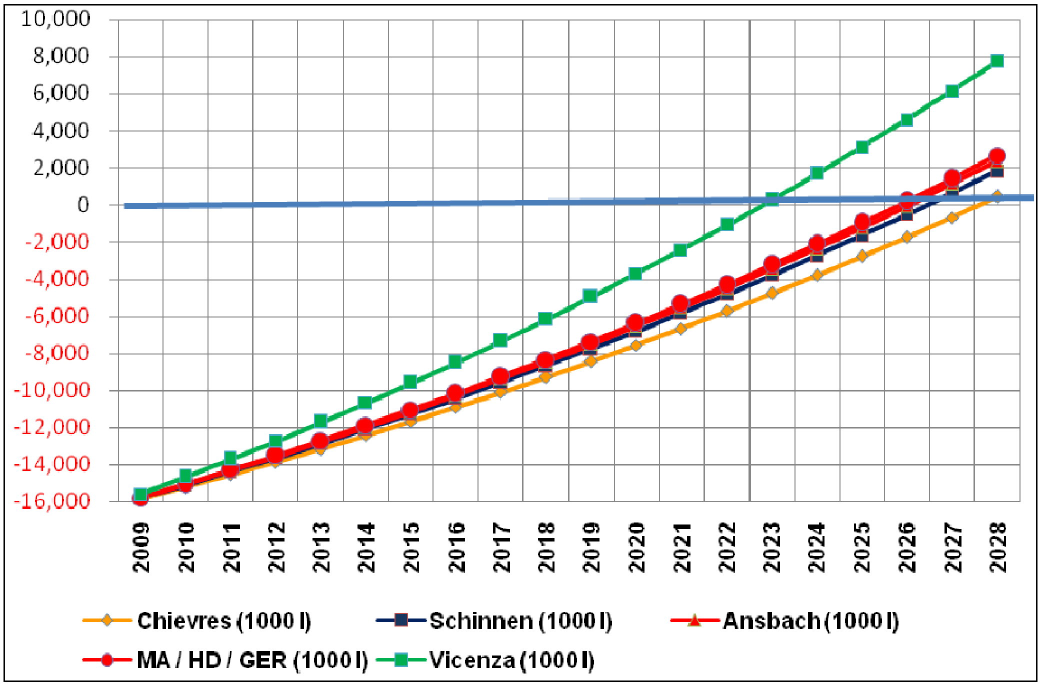



Figure A7. Economic efficiency 1.000 L/day solar system, district heat.

Table A8. Economic efficiency 1.000 L/day solar system (district heat).

| Location | Chievres | Schinnen | Ansbach | MA/HD/GER | Vicenza |
|---|---|---|---|---|---|
| Investment (€) | 16.500 | 16.500 | 16.500 | 16.500 | 16.500 |
| Energy Savings/first year (€) | 630 | 682 | 701 | 713 | 901 |
| Amortization period without capital costs (years) | 19 | 18 | 18 | 17 | 14 |

A Solar System with this capacity substituting district heat supply is not recommended for any location. If the investment price will be significantly lower it might get certain economic efficiency in Vicenza, but not in the other locations.

**Economic Efficiency – District Heat – 2.000 L**

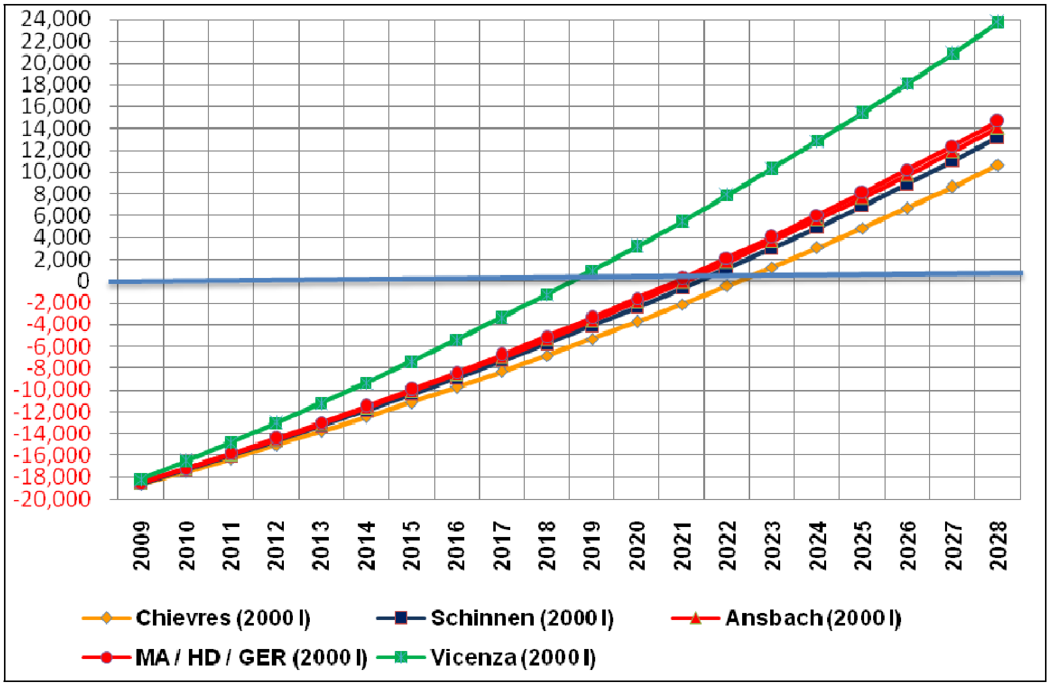



Figure A8. Economic efficiency 2.000 L/day solar system, district heat.

Table A9. Economic efficiency 2.000 L/day solar system (district heat).

| Location | Chievres | Schinnen | Ansbach | MA/HD/GER | Vicenza |
|---|---|---|---|---|---|
| Investment (€) | 19.800 | 19.800 | 19.800 | 19.800 | 19.800 |
| Energy Savings/first year (€) | 1.133 | 1.227 | 1.260 | 1.282 | 1.619 |
| Amortization period without capital costs (years) | 14 | 13 | 13 | 12 | 10 |

A Solar System with this capacity at the basic investment price substituting a district heat supply a certain economic efficiency can be achieved. The situation will improve if the investment price will be significantly lower as the following Figure A9 and Table A10 show.

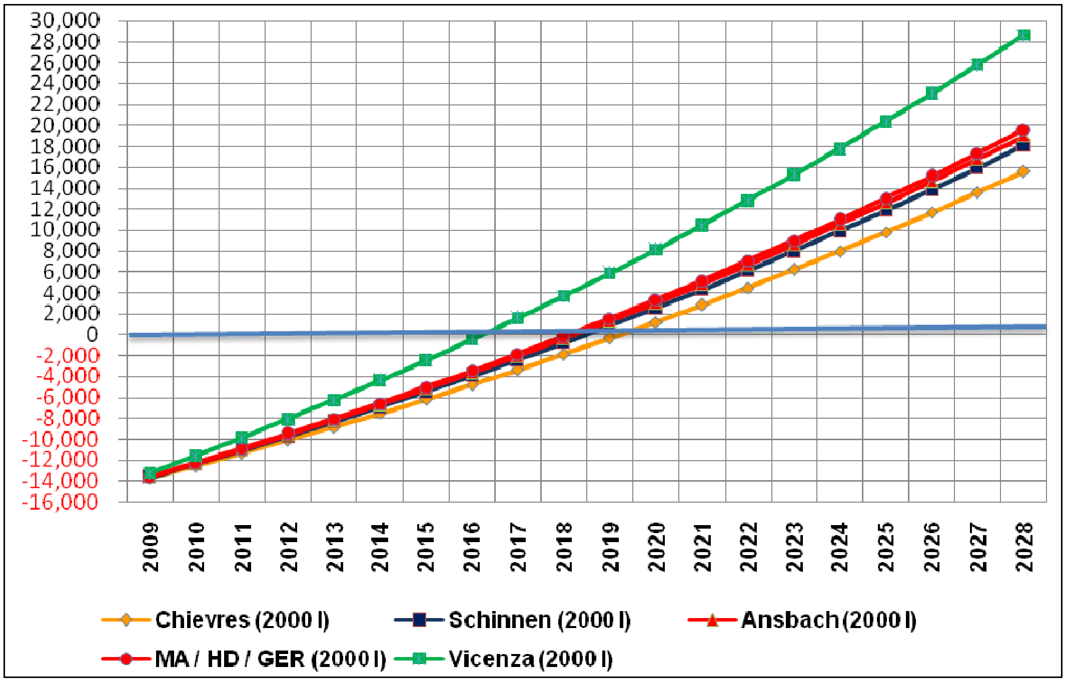



Figure A9. Economic efficiency 2.000 L/day solar system (district heat) (-25% invest).

Table A10. Economic efficiency 2.000 L/day solar system (district heat) (-25% invest)

| Location | Chievres | Schinnen | Ansbach | MA/HD/GER | Vicenza |
|---|---|---|---|---|---|
| Investment (€) | 14.850 | 14.850 | 14.850 | 14.850 | 14.850 |
| Energy Savings/yr (€) | 1.133 | 1.227 | 1.260 | 1.282 | 1.619 |
| Amortization period without capital costs (years) | 11 | 10 | 10 | 10 | 8 |

If the investment price will be decreased by 25 percent the economic efficiency calculations show amortization times of about 10 years in the Northern European locations and less than 10 years in Italy.

## Solar Systems – Conclusions and Recommendations

Table A11 lists the main selection criteria for a decision whether to invest in a Solar System based on economic efficiency.

For the Solar Systems with capacities of 3.000 – 5.000 L/day only the amortization time without price increases are calculated. The results show, that bigger systems have a better economical efficiency.

Table A11. Overview of the economic efficiency of solar systems.

| System Size (L/day) | 1000 | 2000 | 3000 | 4000 | 5000 |
|---|---|---|---|---|---|
| | Orientation Quotation Elco | | Extrapolated figures | | |
| Investment (Basic Price) | 16.500 | 19.800 | 23.562 | 27.803 | 32.530 |
| Investment (Reduced Price) | 12.375 | 14.850 | 17.672 | 20.852 | 24.397 |
| | | | | | |
| Chievres | | | | | |
| Energy saving/yr (€) | -504 | -906 | -1.453 | -2.022 | -2.558 |
| Amortization Time without price increase (years) | 33 | 22 | 16 | 14 | 13 |
| Amortization Time with 3% price increase (years) | 23 | 17 | not calculated | | |
| Amortization Time with 3% price increase (years) - reduced investment price | 19 | 14 | | | |
| | | | | | |
| Schinnen | | | | | |
| Energy saving/yr (€) | -546 | -981 | -1.574 | -2.191 | -2.770 |
| Amortization Time without price increase (years) | 30 | 20 | 15 | 13 | 12 |
| Amortization Time with 3% price increase (years) | 21 | 16 | not calculated | | |
| Amortization Time with 3% price increase (years) - reduced investment price | 16 | 12 | | | |
| | | | | | |
| Ansbach | | | | | |
| Energy saving/yr (€) | -561 | -1.008 | -1.617 | -2.250 | -2.846 |
| Amortization Time without price increase (years) | 29 | 20 | 15 | 12 | 11 |
| Amortization Time with 3% price increase (years) | 18 | 13 | not calculated | | |
| Amortization Time with 3% price increase (years) - reduced investment price | 15 | 10 | | | |
| | | | | | |
| MA/HD/GER | | | | | |
| Energy saving/yr (€) | -570 | -1.025 | -1.644 | -2.289 | -2.895 |
| Amortization Time without price increase (years) | 29 | 19 | 14 | 12 | 11 |
| Amortization Time with 3% price increase (years) | 17 | 12 | not calculated | | |
| Amortization Time with 3% price increase (years) - reduced investment price | 15 | 10 | | | |
| | | | | | |

| System Size (L/day) | 1000 | 2000 | 3000 | 4000 | 5000 |
|---|---|---|---|---|---|
| Vicenza | | | | | |
| Energy saving/yr (€) | -721 | -1.295 | -2.077 | -2.891 | -3.656 |
| Amortization Time without price increase (years) | 23 | 15 | 11 | 10 | 9 |
| Amortization Time with 3% price increase (years) | 17 | 12 | not calculated | | |
| Amortization Time with 3% price increase (years) - reduced investment price | 14 | 9 | | | |

In Schinnen and Chievres, the climate conditions are not very promising. To invest in Solar Systems in those areas is not recommended. Even with a 25 percent reduced investment price the amortization times will be higher than 10 years for smaller Solar Systems (1.000 – 2.000 L/day) and approx. 10 years for larger Solar Systems.

The economic efficiency in the German locations is slightly better, but the amortization times in Germany is longer than 10 years for smaller Solar Systems. The investment price is the main economic issue. If a lower investment price can be achieved, Solar Systems with capacities larger than 2.000 L/day may have amortization times of less than 10 years.

Comparable to the results of the PV-System report it is very economical to install Solar Systems in Vicenza. Even Solar Systems with capacities starting at 2.000 L/day can achieve amortization times of less than 10 years. The investment price is the criteria for profitable Solar Systems in Vicenza as well.

The economic efficiency situation will become better and better if the yearly price increase of the energy costs will be higher than 3 percent. Typically, the heat price of district heat supply is higher than that of a local fuel oil/natural gas heat supply. In case of a district heat supply, the economic efficiency values are higher.

In any case, to achieve amortization times of less than 5 years with Solar Systems is probably not possible. It must be remembered that capital costs are not included in the calculations; if they were included, the amortization times would be longer.

# Buildings Appropriate for Solar Systems

## Location Heidelberg

Figure A10. Bldg 31/Dining Facilities at Heidelberg.

Table A12. Energy overview of Bldg 31/Dining Facilities at Heidelberg..

| Parameter | Measure |
|---|---|
| domestic hot water requirement/day | 5.000 L |
| Investment (basic price/reduced price approx euro) | 32.500/24.400 |
| Amortization time (at basic price/approx. years) | 10 |
| Amortization time (at reduced price/approx years) | 7 |
| Appropriate for dish washers | No |
| Detailed design recommended | Yes |


Figure A11. Bldg 37/Dining Facilities at Heidelberg.

Table A13. Energy overview of Bldg 37/Dining Facilities at Heidelberg.

| Parameter | Measure |
|---|---|
| Domestic hot water requirement/day | 1.000 L |
| Investment (basic price/reduced price approx euro) | 16.500/12.400 |
| Amortization time (at basic price/approx. years) | 17 |
| Amortization time (at reduced price/approx years) | 14 |
| Appropriate for dish washers | No |
| Detailed design recommended | No |

Figure A12. Air Base/Fire Brigade at Heidelberg.

Table A14. Energy overview of Air Base/Fire Brigade at Heidelberg.

| Parameter | Measure |
|---|---|
| Domestic hot water requirement/day | 1.000 L |
| Investment (basic price/reduced price approx euro) | 16.500/12.400 |
| Amortization time (at basic price/approx. years) | 17 |
| Amortization time (at reduced price/approx years): | 14 |
| Appropriate for dish washers | No |
| Detailed Design recommended | No |


Figure A13. Bldg 4545/Family Entertainment at Heidelberg.

Table A15. Energy overview of Bldg 4545/Family Entertainment at Heidelberg.

| Parameter | Measure |
|---|---|
| Domestic hot water requirement/day | 2.000 L |
| Investment (basic price/reduced price approx euro) | 19.800/14.850 |
| Amortization time (at basic price/approx. years) | 12 |
| Amortization time (at reduced price/approx years) | 9 |
| Appropriate for dish washers | No |
| Detailed design recommended: | Yes |

Figure A14. Wingers Club/Restaurant. at Heidelberg.

Table A16. Energy overview of Wingers Club/Restaurant. at Heidelberg.

| Parameter | Measure |
|---|---|
| Domestic hot water requirement/day | 0.000 L |
| Investment (basic price/reduced price approx euro) | 19.800/14.850 |
| Amortization time (at basic price/approx. years) | 12 |
| Amortization time (at reduced price/approx years) | 9 |
| Appropriate for dish washers | No |
| Detailed design recommended | Yes |

## Location Mannheim

Figure A15. Bldg 25/Gymnasium at Mannheim.

Table A17. Energy overview of Bldg 25/Gymnasium at Mannheim.

| Parameter | Measure |
|---|---|
| Domestic hot water requirement/day (estimated) | 2.000 L |
| Investment (basic price/reduced price approx euro) | 19.800/14.850 |
| Amortization time (at basic price/approx. years) | 12 |
| Amortization time (at reduced price/approx years) | 9 |
| Appropriate for dish washers | No |
| Detailed design recommended | Yes |

## Location Schinnen

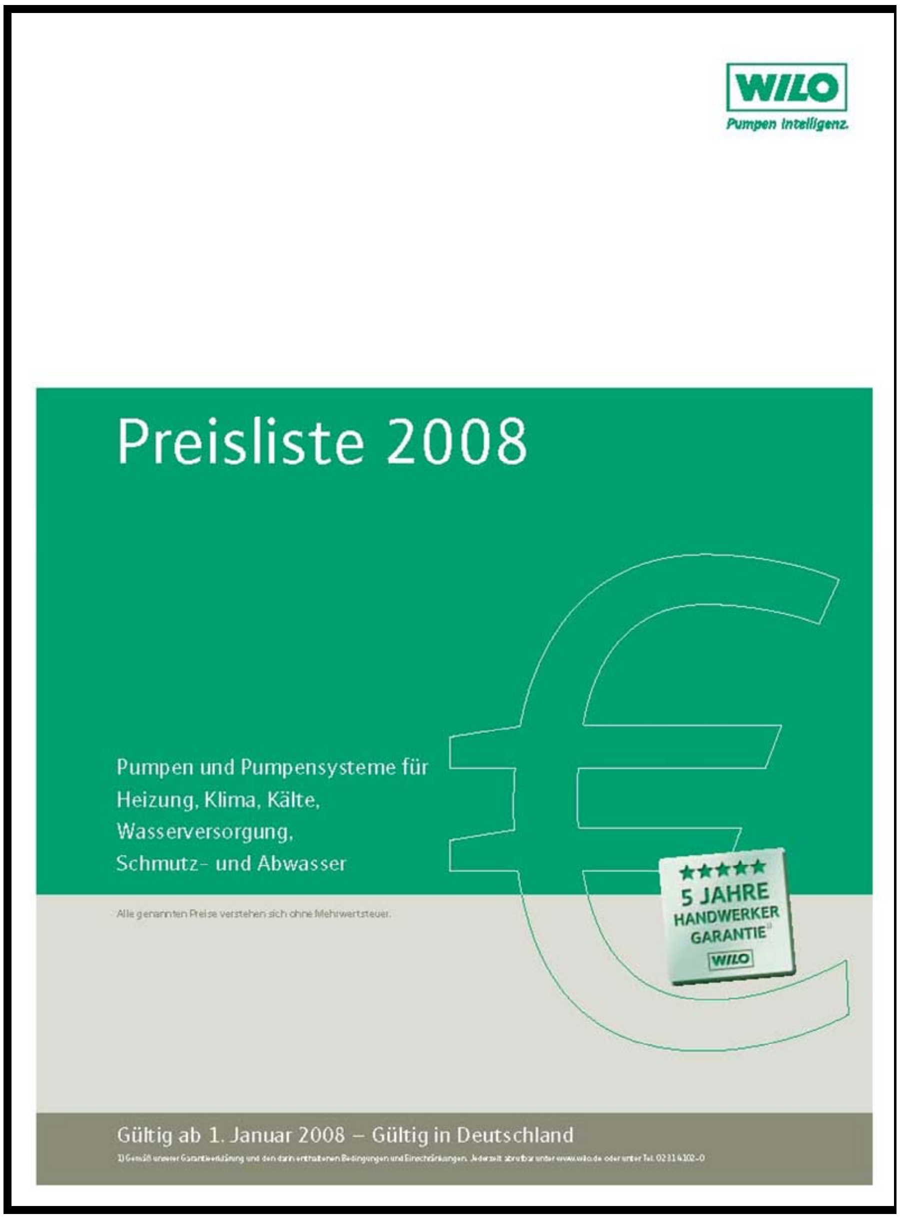

Figure A16. Bldg 42/Fitness Center at Schinnen.

Table A18. Energy overview of Bldg 42/Fitness Center at Schinnen.

| Parameter | Measure |
|---|---|
| Domestic hot water requirement/day (estimated) | 2.000 L |
| Investment (basic price/reduced price approx euro) | 19.800/14.850 |
| Amortization time (at basic price/approx. years) | 16 |
| Amortization time (at reduced price/approx years) | 12 |
| Appropriate for dish washers | No |
| Detailed design recommended: | No |

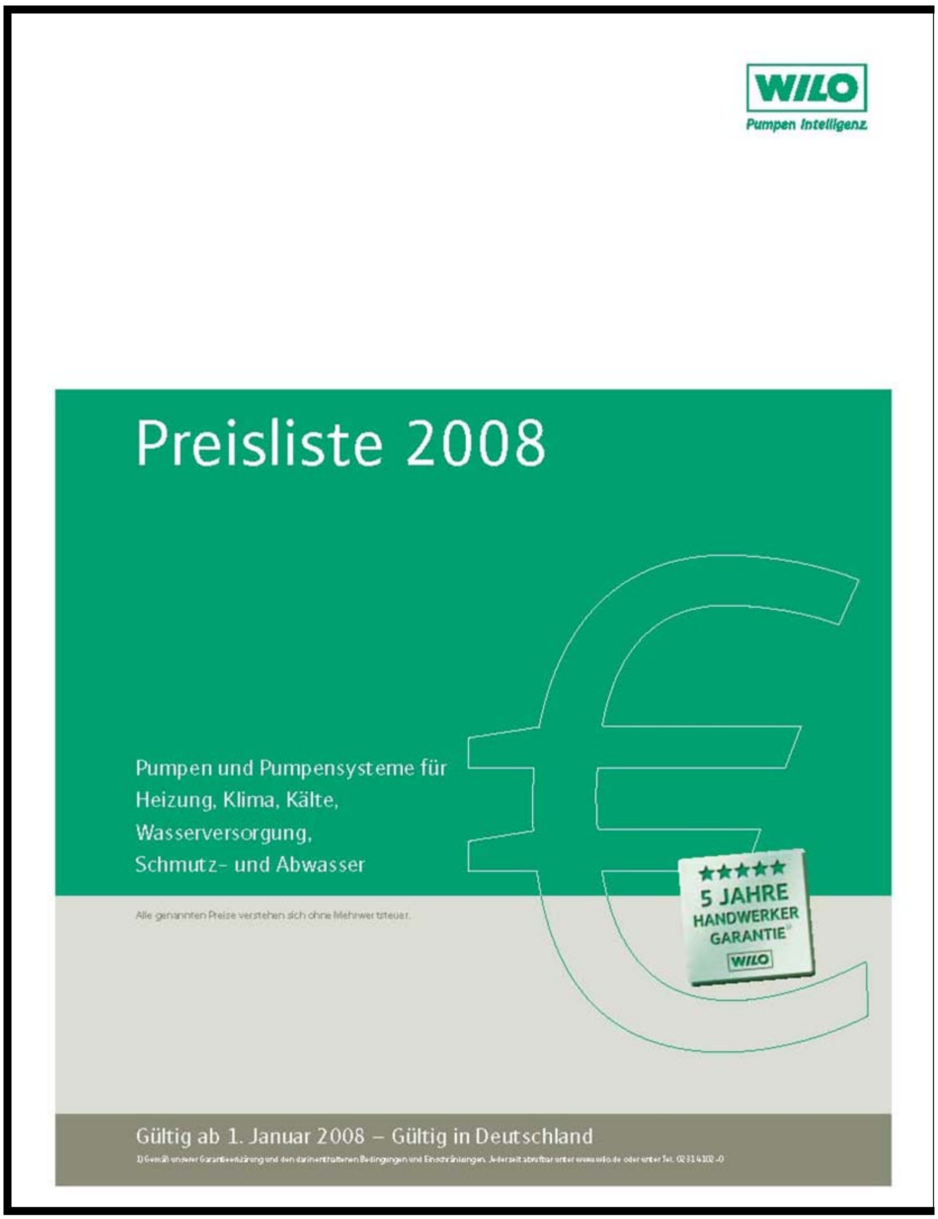
# Appendix B: Pump Price List

Left-mouse-click the image below to open the electronic price list document.



# Appendix C: Pump Replacement Recommendations

Left-mouse-click the image below to open the electronic pump replacement document.



# Appendix D: Radiant Heat Drawings

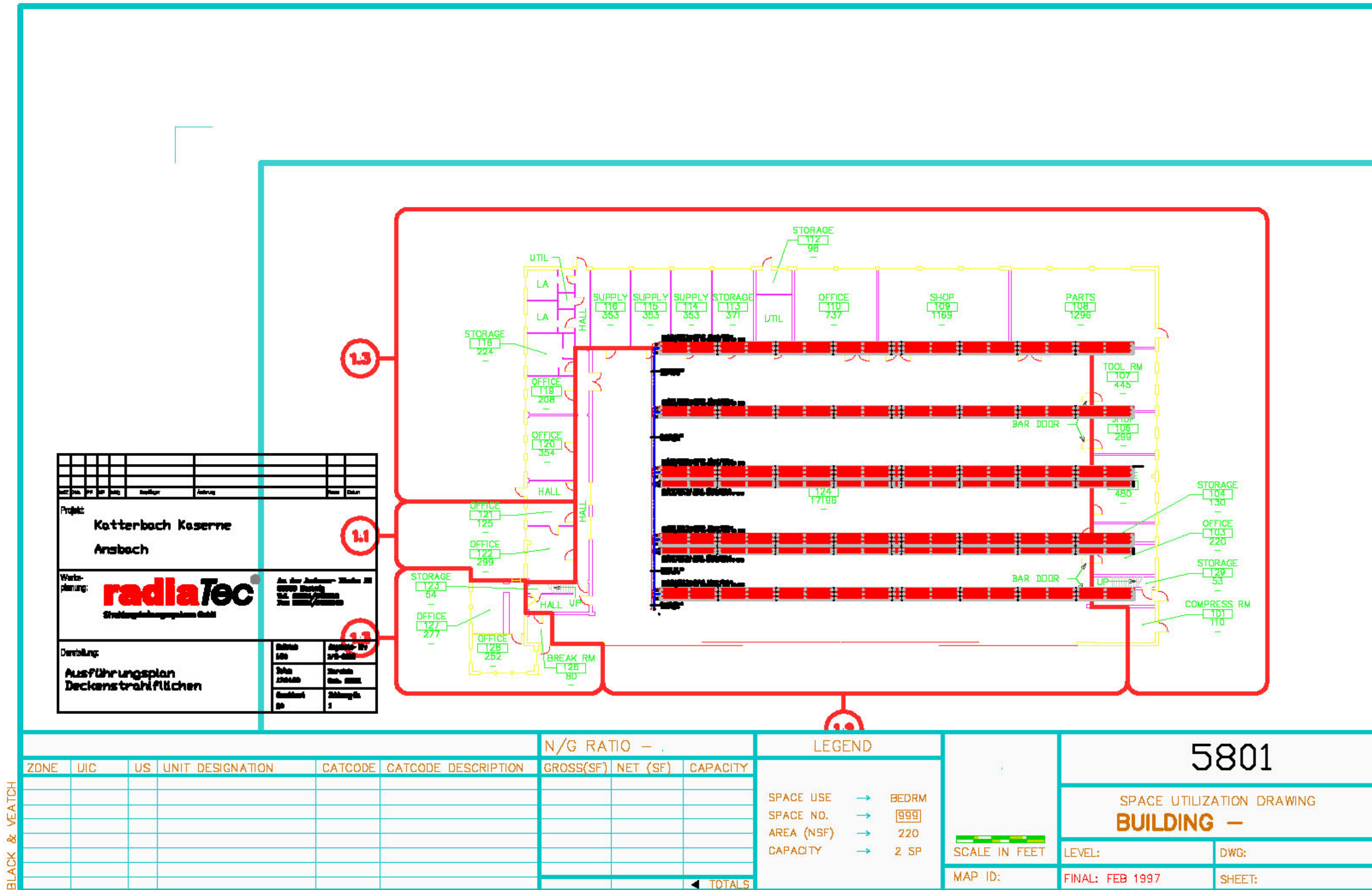



Figure D1. Radiant heating equipment design for Bldg 5801.

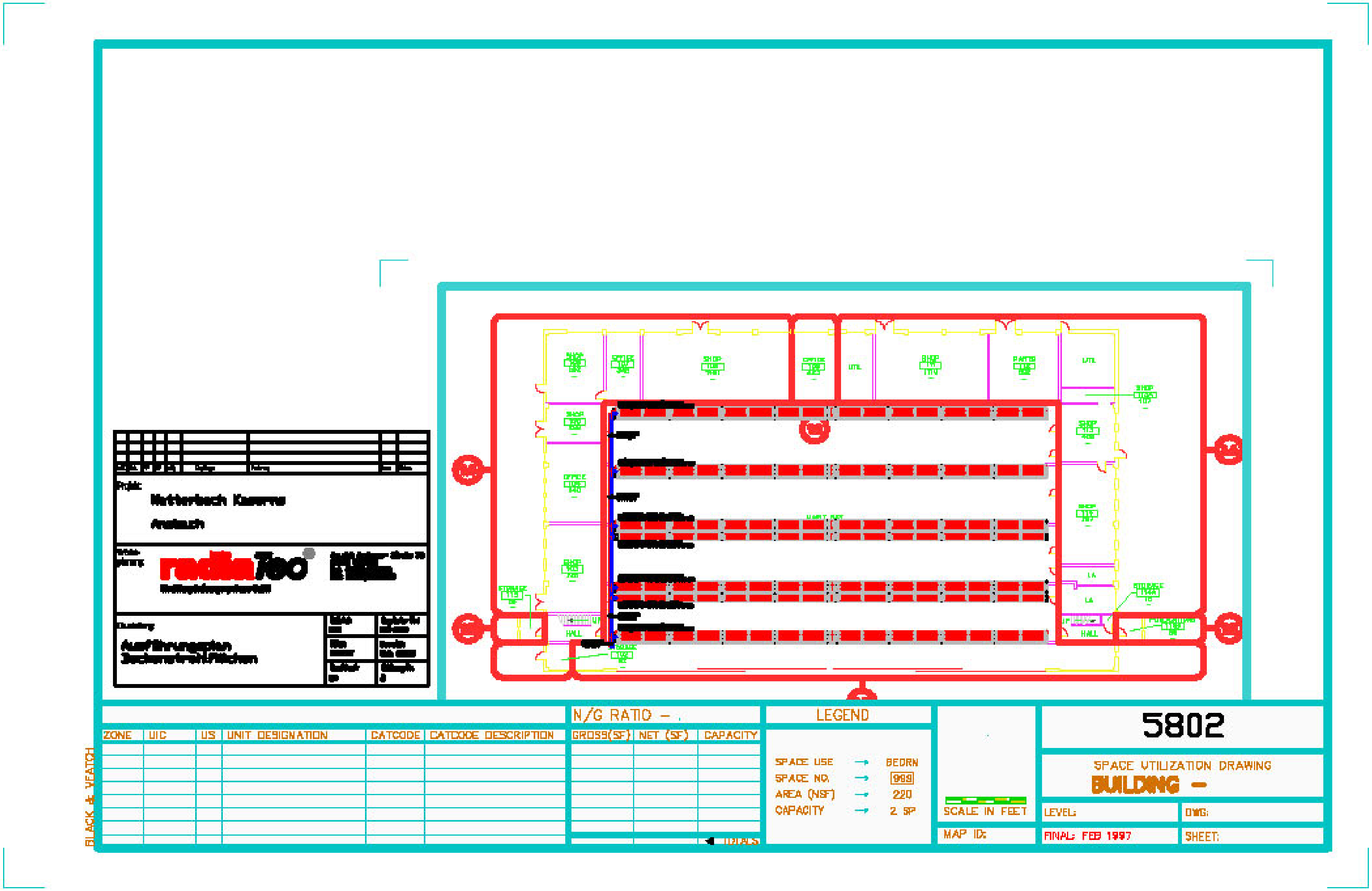



Figure D2. Radiant heating equipment design for Bldg 5802.

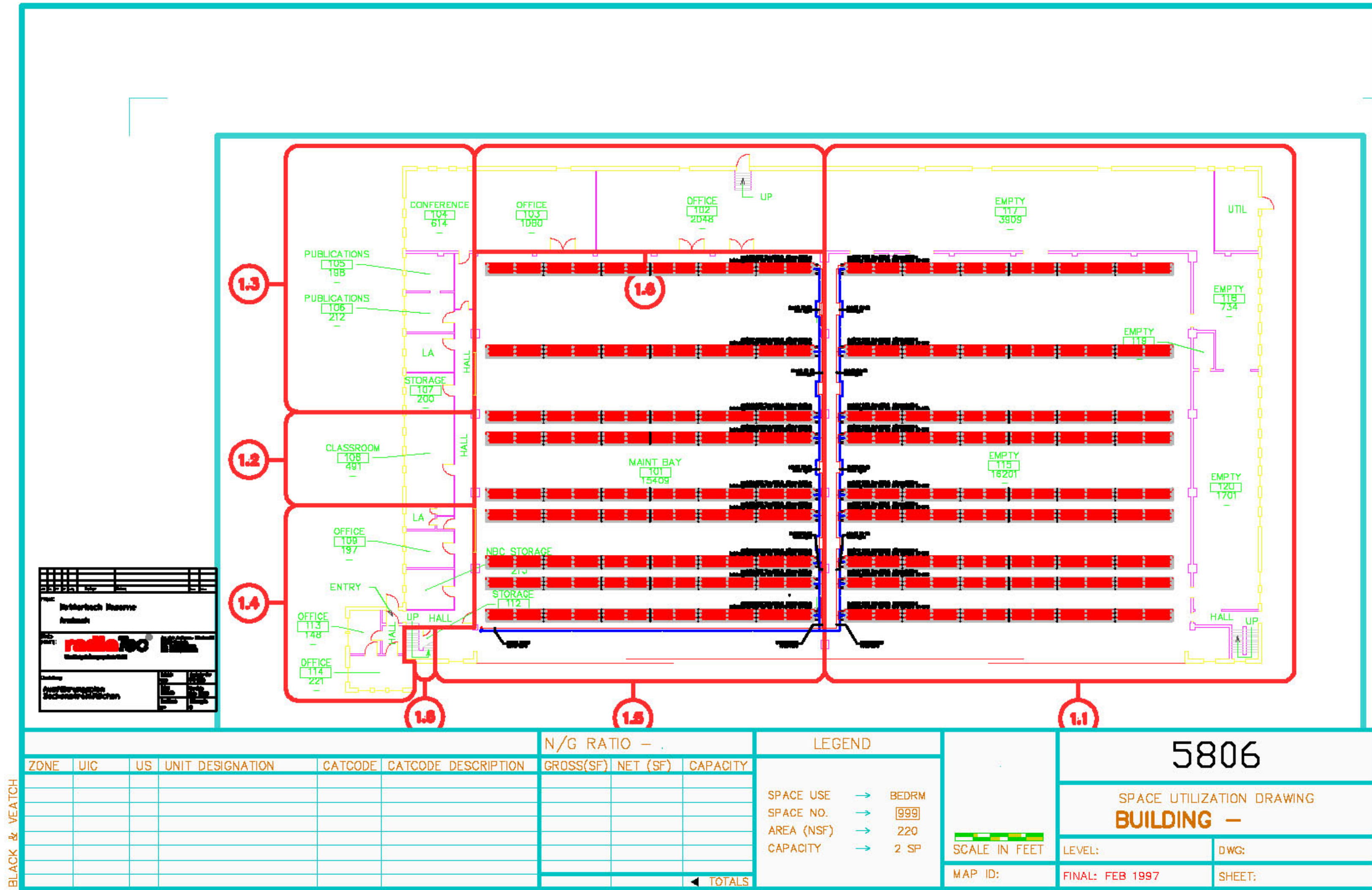



Figure D3. Radiant heating equipment design for Bldg 5806.

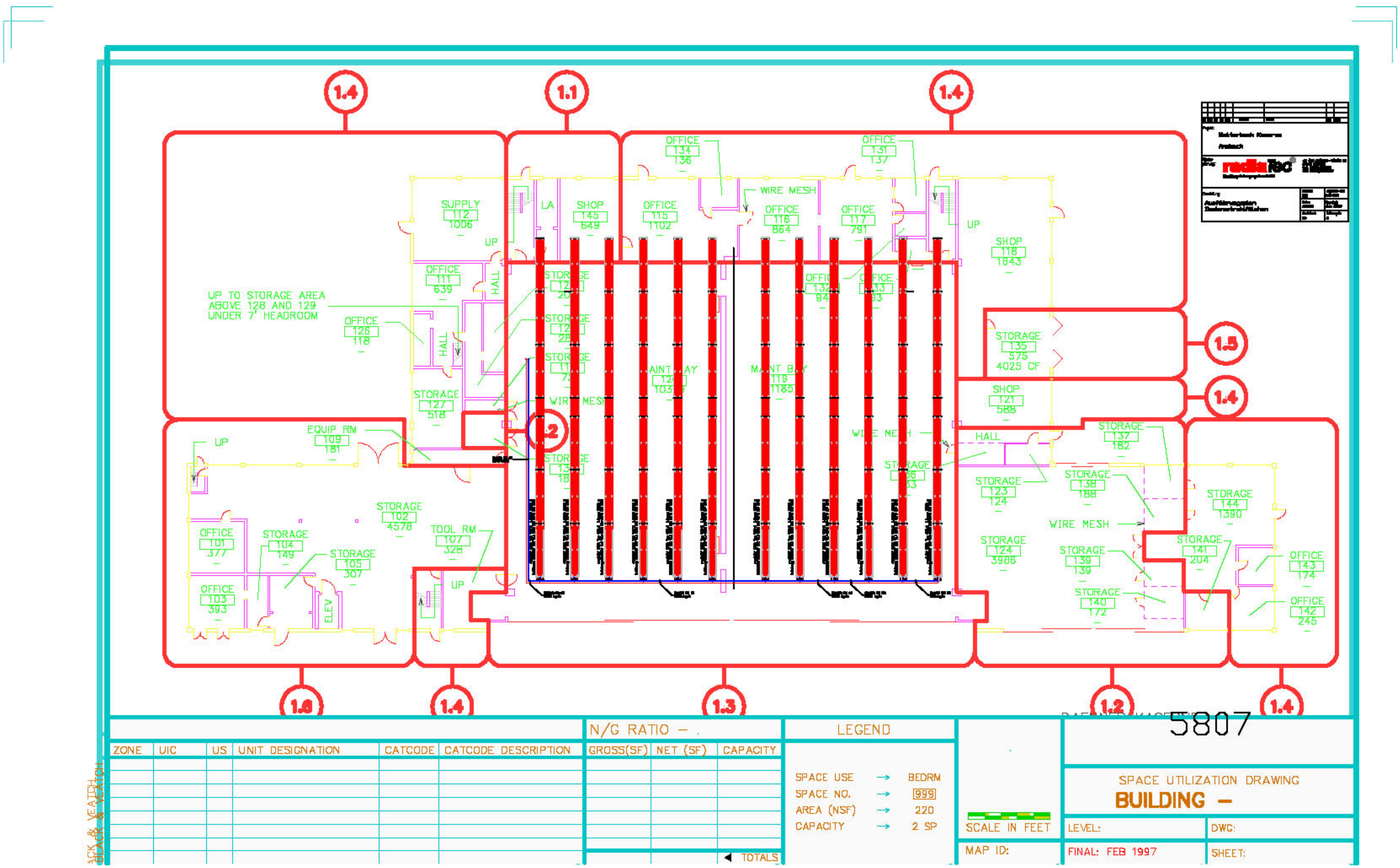



Figure D4. Radiant heating equipment design for Bldg 5807.

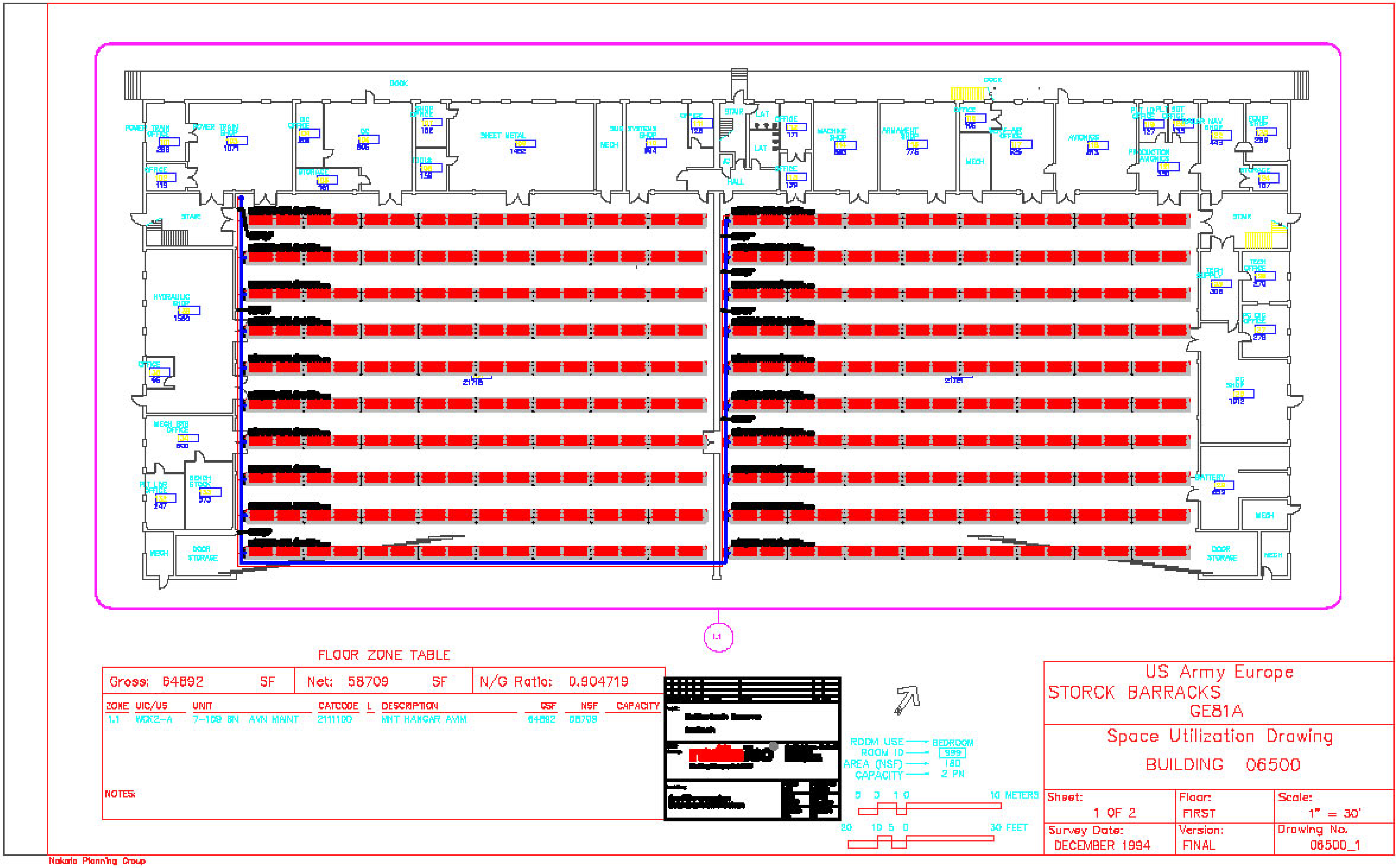



Figure D5. Radiant heating equipment design for Bldg 6500.

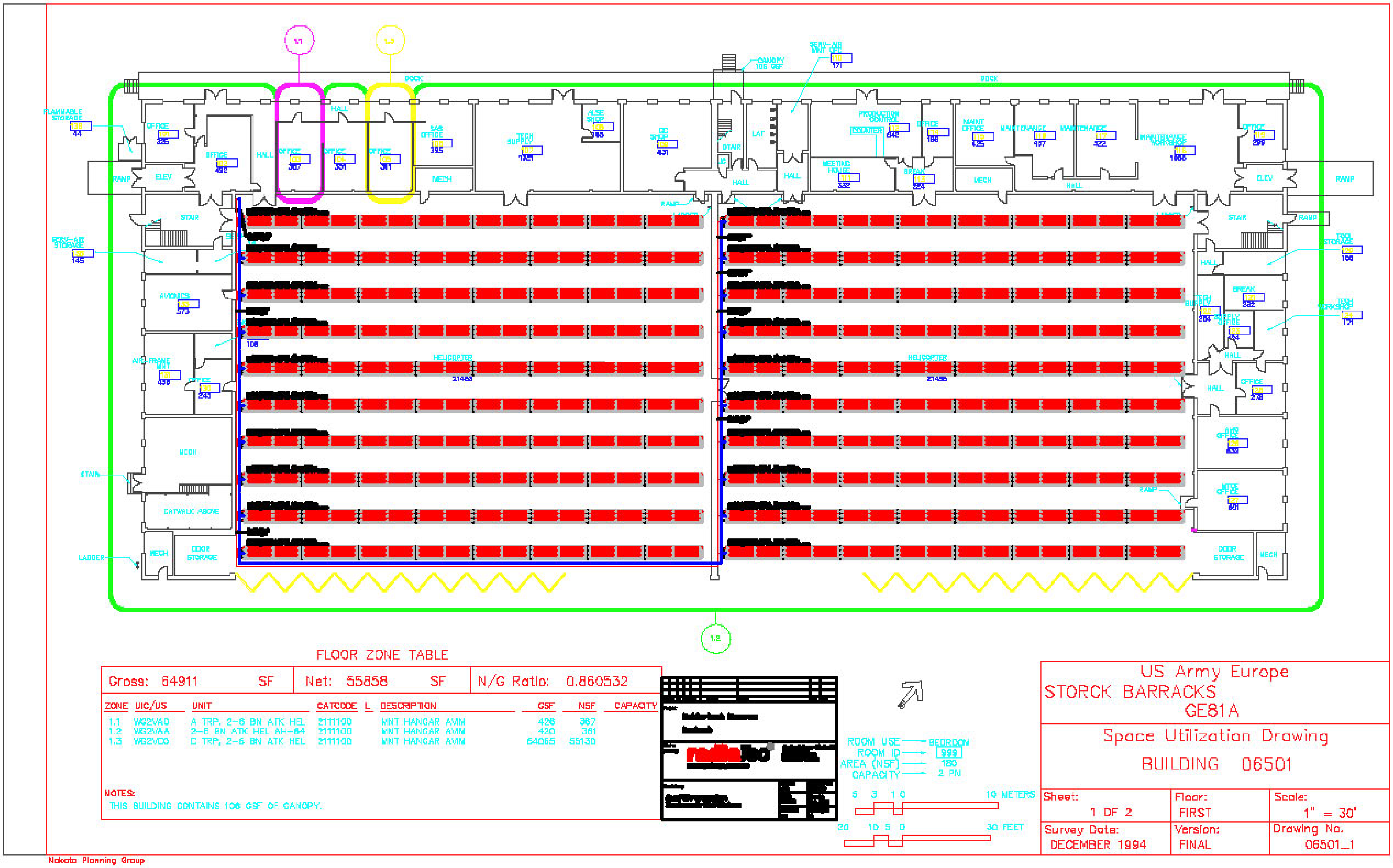



Figure D6. Radiant heating equipment design for Bldg 6501.

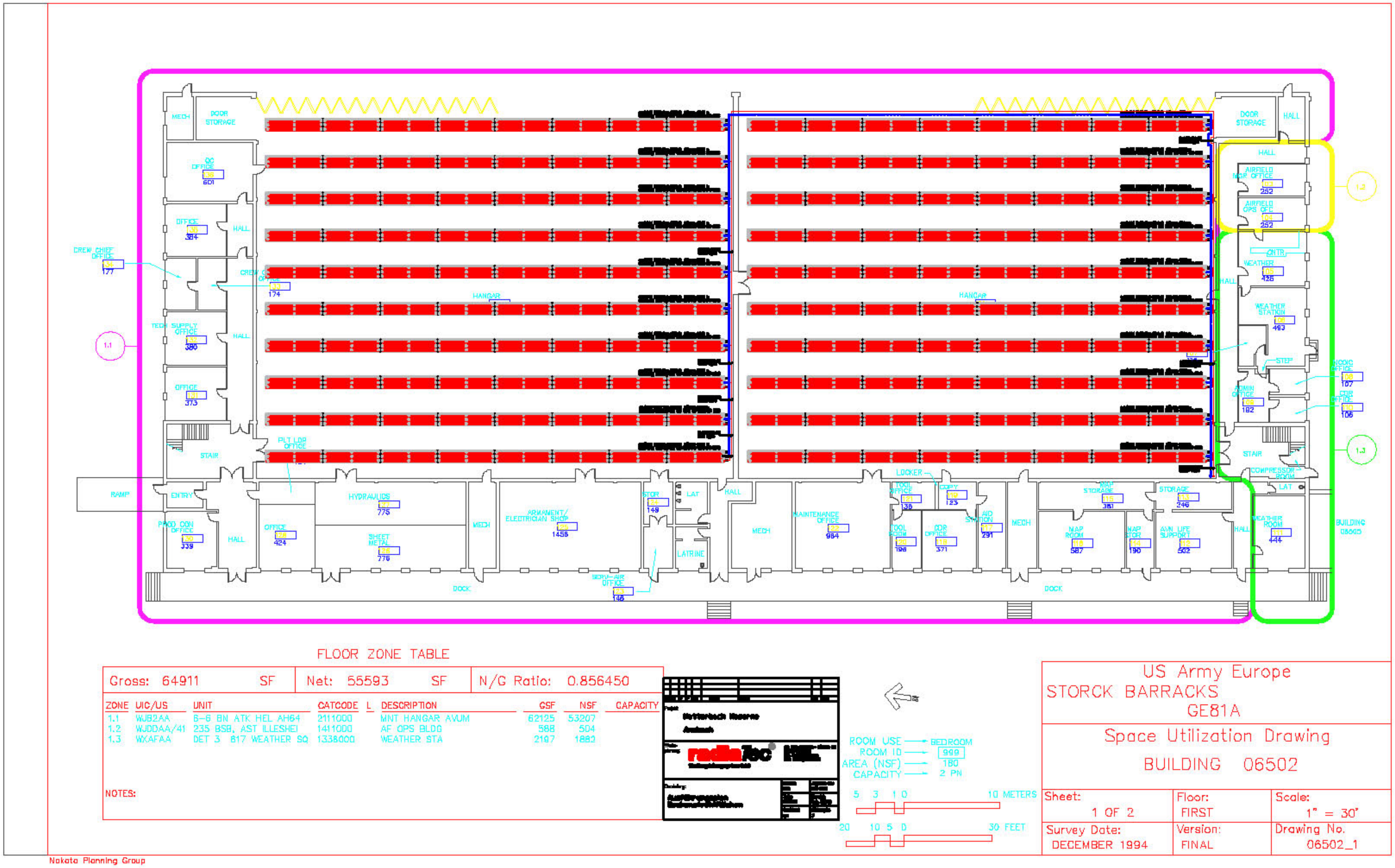



Figure D7. Radiant heating equipment design for Bldg 6502.

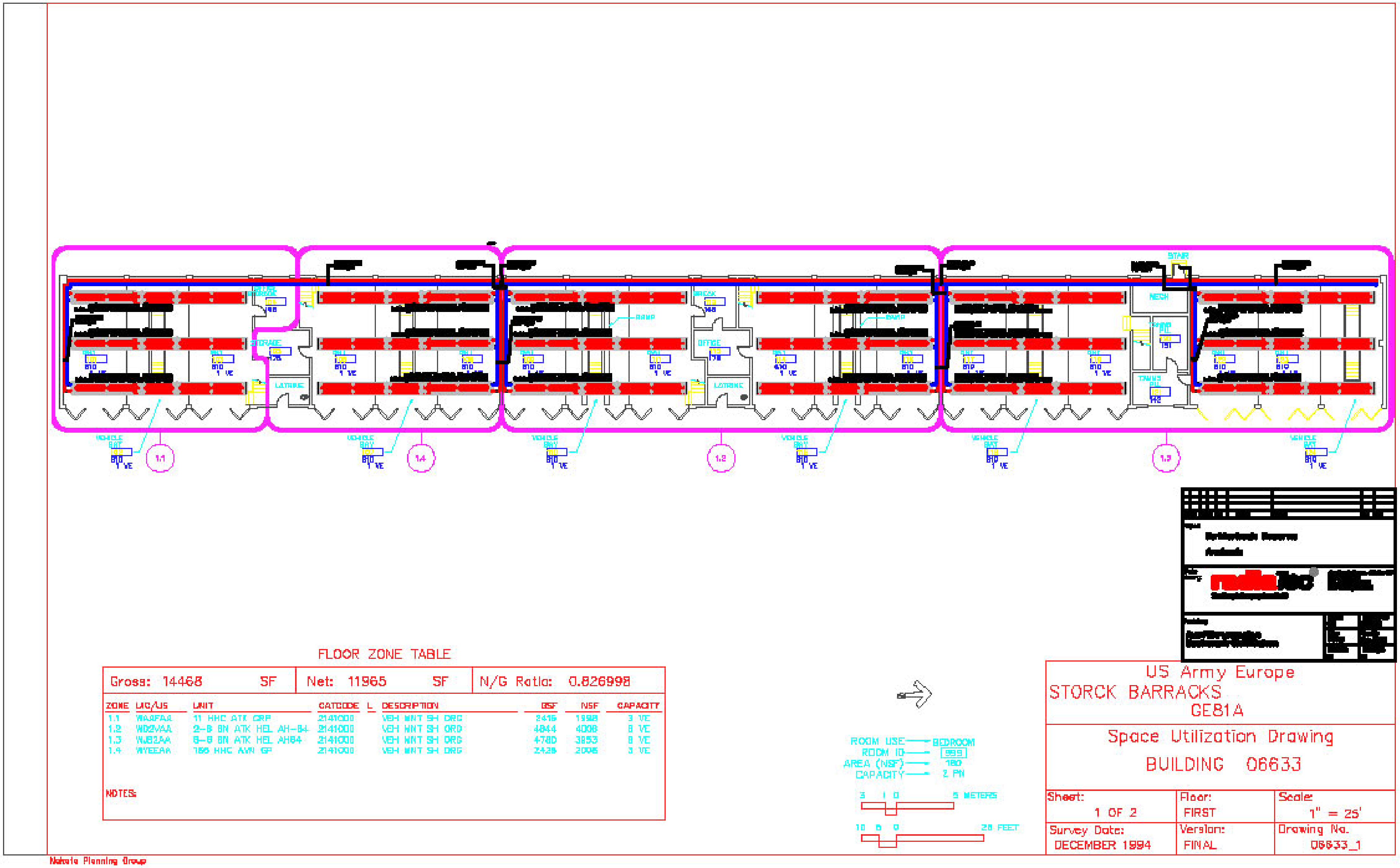



Figure D8. Radiant heating equipment design for Bldg 6633.

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**14. ABSTRACT**
Energy Optimization Assessment was conducted at several Army installations in Germany as a part of the International Energy Agency (IEA) Energy Conservation in Buildings and Community Systems (ECBCS) initiative to identify energy inefficiencies and wastes and propose energy-related projects with applicable funding and execution methods that could enable installations to better meet the energy reduction requirements mandated by Executive Order 13123 and Energy Policy Act (EPAct) 2005. Previous studies were conducted at: Fort Stewart GA; Fort Bliss TX; West Point Military Academy, NY; U.S. Army Garrison (USAG) Vicenza, Italy; and several sites in Germany. Results of those studies are documented separately. The study was conducted by the Energy Team, composed of the Construction Engineering Research Laboratory (ERDC-CERL) researchers and their subject matter experts. The scope of the Annex 46 Energy Optimization Assessment included a Level I study of the central energy plants and associated steam distribution systems providing heat to representative administrative buildings, laundry, dining facilities and other buildings and an analysis of their building envelopes, ventilation air systems, and lighting. The study identified 87 different energy conservation measures (ECMs) that would reduce annual electrical use by up to 9.3 million kWh and thermal energy use by 27,545 MMBtu/yr.

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